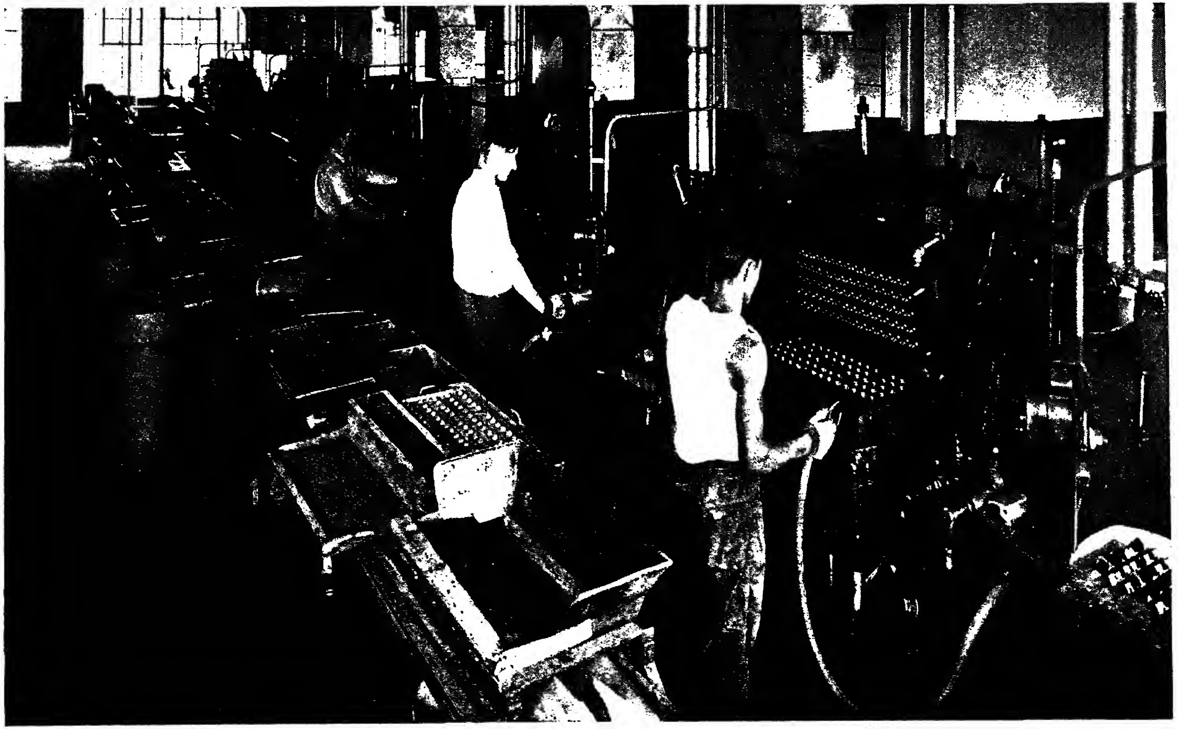

FRONTISPIECE.—Modern molding plant. Note ventilating duct over each press for removal of excess heat. Material supplied in barrels has been tableted to spherical shape and is loaded into the mold by means of a loading board, as in center foreground. Hopper in foreground receives molded work and delivers immediately below to belt conveyor for removal. Each unit equipped with compressed air for cleaning dies, and with electric timer indicating, by light, completion of each cycle. Production per unit, 8000 to 10,000 pieces per 8-hr. day. Annual United States production of such radio-tube bases approximately 100,000,000 to 150,000,000. (*Westinghouse Lamp Co.*)

PLASTIC MOLDING

AN INTRODUCTION TO THE MATERIALS, EQUIPMENT AND METHODS USED IN THE FABRICATION OF PLASTIC PRODUCTS

BY

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PREFACE

The art of forming objects in molds is ages old, embracing, as it does, the casting of metals, the blowing of glass, and the shaping of clay subsequently finished by baking. Although industries founded on this knowledge have persisted for centuries with little change in method or equipment, the molding of plastics, being dependent upon a machine age, is a relatively new-born industry.

Founded on the molding of natural plastics, this industry showed little development before the introduction of synthetic materials. These newer plastics, almost unlimited in supply and having in many cases desirable properties not found in natural materials, have opened up new fields of application for molded products. The most remarkable development has come about in the manufacture of precise parts suitable for electrical insulation and mechanical uses. In these fields particularly, the phenomenal growth of the industry during the past twenty years has been due to the class of synthetic materials known as thermosetting plastics.

In writing this book the author has attempted to present a general view of the methods and equipment used in the industry, in the interest of the manufacturer, the user of molded products, and the general reader. Particular stress on the molding of thermosetting plastics may be justified by the present importance of such materials and the probability that future plastics will be handled with substantially the same methods and equipment. In regard to the materials discussed, in view of the volumes available on this phase of the subject,

detailed chemical data have been considered unwarranted in a text of this scope.

For much detailed information and for the generous loan of illustrative material the author wishes to acknowledge the important contributions of Mr. Charles F. Burroughs and Mr. Walter E. Rahm, of the Burroughs Engineering Company. Other contributions are acknowledged as they occur throughout the book.

LOUIS F. RAHM.

PRINCETON, NEW JERSEY,
September, 1933.

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PART I

THE MOLDING PROCESS AND THE PLASTICS

CHAPTER I

THE MOLDING PROCESS

Elementary Process.

The process of molding plastics consists essentially of placing the molding material in a mold, to which sufficient heat is supplied to cause plasticity of the material, and to which sufficient pressure is applied to force this plastic mass to take the shape of the mold cavity. In the elementary process, a subsequent chilling operation is required to insure rigidity and permanence of shape of the molded product. The requirements of heat and pressure are inherent in any process of plastic molding, although the application of these may alter the foregoing process to suit the particular characteristics of individual plastics. The two types of plastics known as thermoplastic and thermosetting permit the greatest variation from the original process described.

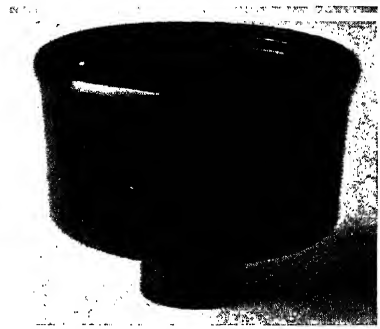

Fig. 1.—Spinning bucket used in rayon manufacture. Example of precise molding of phenol-formaldehyde material. Weight 4½ lb. Diameter 7½ in. Tolerance in eccentricity limited to 2½ thousandths of an inch. In use buckets run at 5000 to 7000 r.p.m. and last indefinitely. Original buckets displaced by this newer material cost several times more initially, and had a life of perhaps 3 to 6 mo.

Variations of Process.

In the case of a thermoplastic, addition of heat to produce plasticity results in a physical change of the material only, unless unduly prolonged or applied at an

excessive temperature. Such materials may be preheated to plasticity before introduction into the mold, effecting great economies both in molding time and in heat. The process thus becomes one of forming a material either partly or entirely plastic in a mold which furnishes little or no heat to the material and may therefore be kept at a nominal temperature. In the extreme, the mold may be cold enough to chill the plastic to permanent shape immediately after its formation, though such cases are the exception rather than the rule. Since the degree of plasticity of a thermoplastic increases as the temperature is raised to a maximum safe limit, it may be seen that the pressure required to form such material depends upon the temperature. This fact permits considerable variation in the temperatures and pressures used to mold such plastics and a degree of latitude in control of these two factors which is not possible with all materials.

All thermoplastics lend themselves readily to the more special process known as injection molding. In this process the material is heated to plasticity in a cylinder, from which it may be forced into a mold initially closed, and there chilled to permanent shape. While for special work this method may be employed to advantage, a relatively small amount of molding is done in this way, although there has been a revival of interest in this process within the past few years.

Some thermoplastics are adaptable to the more special process known as blowing, the aim of which is to produce hollow molded goods. This method employs the hydrostatic pressure of air or steam between two sheets of plastic material to force this stock against the walls of the mold. Depending upon conditions, the material may, or may not, be heated before placing in the mold but must be chilled before ejection, as in the general molding method.

While injection molding and blowing have been employed for many years, neither process has contributed greatly to the phenomenal growth of the molding industry of the past twenty years. This growth has been based chiefly on solid molded goods produced by the more general method, and occasioned by the introduction of plastics having in many cases more desirable proper-

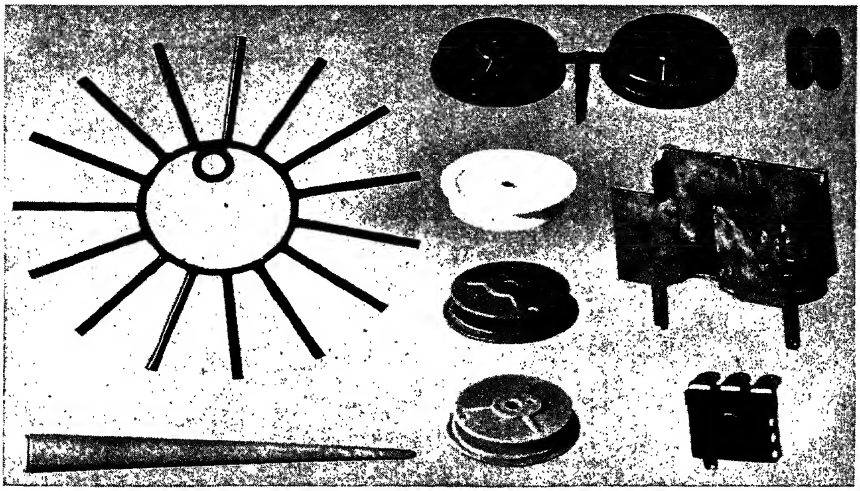

FIG. 2.—Example of injection molding. Note, in general, smallness and complication of parts to which this method of molding is particularly well suited. Size may be judged by fountain-pen cap in lower left. Material—cellulose acetate. (*DuPont Viscoloid Co.*)

ties than those used previously. Of these, the thermosetting plastics have been the most important.

A thermosetting plastic is one which undergoes a chemical change upon the addition of heat and which does not soften or appreciably deform if later reheated even to the molding temperature, which in this case is well defined. In the general process of molding such plastics, relatively little preliminary heating, or preheating, is possible, owing to the nature of the material. The material must be heated to plasticity chiefly after introduction into

the mold and must be held for an appreciable time under pressure in the mold at its proper molding temperature until reaction is complete and the plastic is cured.

Upon curing, the article is at once rigid and may be ejected immediately, *i.e.*, while it is still hot. Chilling is sometimes done, to offset shrinkage in special cases, but

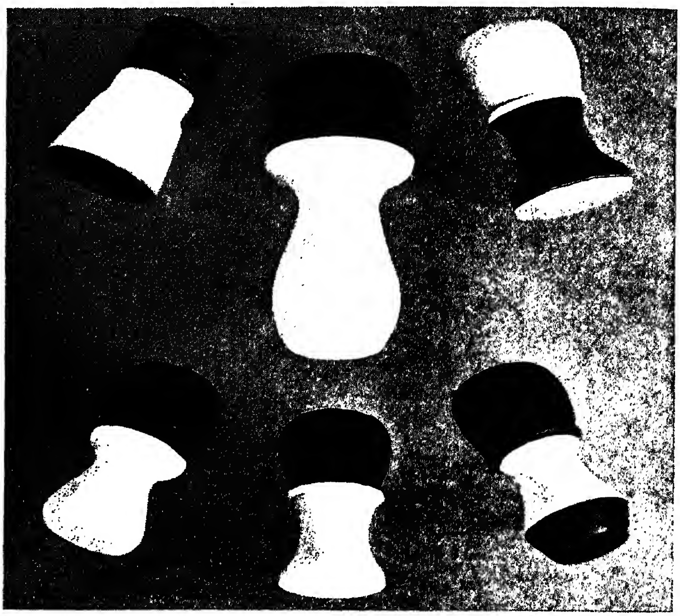

FIG. 3.—Example of blown work. The brush handles shown were blown from tube stock sufficiently thick to provide requisite strength avoiding use of core. Material—pyroxylin. (*DuPont Viscoloid Co.*)

the bulk of thermosetting plastic goods is produced in molds kept continually heated. This simplification of the original process is a distinct advantage in plastic molding, from the standpoint of economy both in the heating medium and in the operating time.

Only within the past few years has the injection process been successfully applied to thermosetting plastics. Since the material cannot withstand sustained preheat-

ing, it is essential that it be injected into the mold immediately upon its becoming plastic and that the extruding machine be loaded only with the amount of material required for each mold charge. In spite of the difficulties inherent in this process, it is used commercially for special work, augmenting rather than displacing the general method.

FIG. 4.—Hollow articles blown from sheet stock. A typical application of pyroxylin. Articles are sprayed to obtain multiple-color effects. (*DuPont Viscoloid Co.*)

As regards blowing of thermosetting plastics, the nature of the material is not suited to the process, and no serious attempts have been made in this direction. Indications are that the material would require so much preparation for such a process as to make any method commercially impractical.

Tableting.

Closely associated with the actual molding of plastics, and usually considered as a part of the process, is the preparation of the molding material for loading into

the mold. While a small excess above the amount required to fill the mold is in some cases unavoidable, it is essential that this excess be a minimum, even though this waste or scrap may be reworked and used later. The thermoplastic materials which permit of sufficient preheating may be cut up or otherwise measured into individual charges as needed by the operator. While the results are not exact, the simplicity of this method justifies its use in connection with relatively cheap or low-grade materials. Materials which are rigid during loading may be stamped or blanked out from sheet stock to the size and shape desired. This method of preparation, while still used to some extent, especially for so-called die-pressing work, usually leaves considerable scrap to be reworked and does not compare favorably with the more modern method of tableting.

Tableting presupposes that the material is in a powdered or finely divided form. Materials may be deliberately reduced to this form by grinding, in order to secure the advantage of economy with which such plastics may be prepared. The powdered material may be automatically measured into individual charges and compacted under a heavy blow, reducing the bulk of the charge very considerably and producing a tablet sufficiently substantial to withstand the handling incident to loading. The bulk of tablets prepared are disks of varying diameter and thickness; but in cases where it is especially desirable to have the material more nearly fit the mold cavity, the tablets may be made the approximate size and shape of the finished article. Such tablets, more properly called preforms, may be produced in a tableting machine as well as the simpler shapes, although at somewhat higher cost.

In any event, the economy resulting from the reduction of waste and the facility gained in loading the mold have made this a standard method of preparing powdered

materials for the molding process. Unusual conditions may require molding directly from loose bulk material, but as a general practice it is to be avoided whenever possible. In addition to the advantages mentioned in regard to tableting lies the possibility of automatic loading of molds with the use of spherical tablets which may

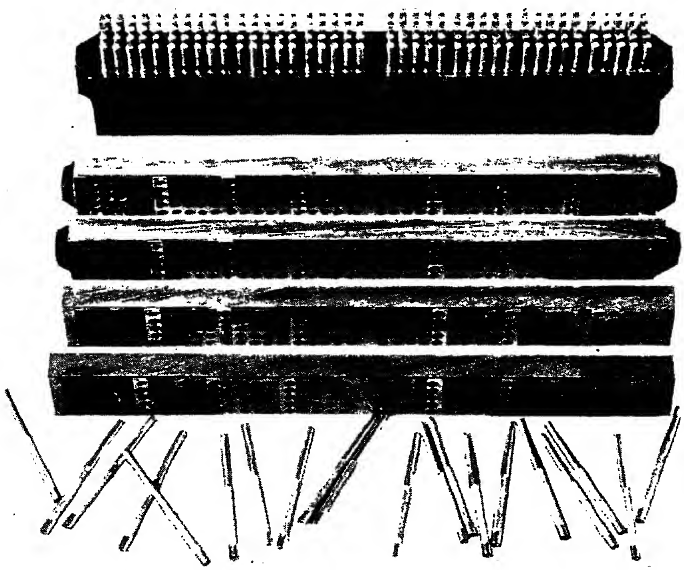

FIG. 5.—Example of preforms and inserts. The four preformed blocks and 200 metal pins are formed into the block above at one operation. Material—Bakelite. (*Bakelite Corp.*)

be fed by gravity to the molds. Although spherical tablets are commonly used, the automatic feed has not as yet been applied but will in all probability come into use when the primary molding equipment is made fully automatic.

Inserts.

Occasionally, conditions require that the product contain pieces of a foreign material, such as wood, metal,

or fiber, molded into the object. The process of molding such work thus includes the additional operation of placing these pieces or inserts in the mold at each loading. Under the best of conditions, the time required for this setting of inserts is appreciable, since the parts not only must be placed properly in the mold but generally require retaining by some device to avoid displacement during molding.

Since molding time has been reduced through quicker curing materials, the tendency has been to avoid inserts whenever possible, through redesign of the molded piece or by subsequent machining operation. Inserts or cores for the purpose of strength or embedded electrical wires and contacts cannot be avoided, but in many cases where the insert cannot be entirely avoided it may be pressed or staked into place after the molding operation. Where the production of work is large enough to justify it, special machines may be developed for the simultaneous staking-in of multiple inserts, instead of molding these in the article.

Heating Media.

In considering in more detail the important factor of heat in the molding process, the various possible heating media, relative convenience of application and operation, and relative costs are the main items of interest. The needs of large production plants are adequately met by the use of steam, but while this is the generally preferred medium, gas and electricity are occasionally considered in small installations.

In the general application of heat, the loaded mold is placed under pressure between the heated platens of a press, where it is heated indirectly by contact with the platen surfaces. The characteristic thermal properties of steam make this almost an ideal medium for maintain-

ing the proper temperature of these platens. Thus with the introduction of a cold mold the removal of heat from the steam condenses some of this steam, with a consequent reduction in volume and pressure. The tendency toward reduced pressure immediately permits more steam to enter, to maintain the original pressure and corresponding temperature. The supply is thus automatically regulated by the demand, and its temperature may be easily controlled at the steam boiler by maintaining the proper pressure. This simple central control is a great advantage where many individual molding units are to be served. With this heating medium, the temperature need never be in excess of the proper molding temperature, since the automatic admission of steam is almost instantaneous and any temperature drop is practically inappreciable in magnitude and momentary in duration.

In contrast to this, gas and electricity require different treatment. In either case there is no such reservoir of heat as the latent heat of the steam, instantly available, and, as may be expected, the drop in temperature of the platens is very marked. This occasions a certain delay while sufficient heat is supplied to restore the initial temperature and leads to two common practices in applying these media. First, the mass of metal in the platens is increased in an effort to obtain heat storage. This leads to increased radiation losses and more bulky equipment and will at best offset only a part of the initial temperature drop. Secondly, in anticipation of the condition, the heat may be supplied at a higher temperature, so that the initial drop may establish the desired molding temperature. This also increases radiation losses and, in addition, unless carefully controlled, may lead to burned material and even temporarily spoiled molds, through overheating. Each medium

requires control, at the molding unit, and whereas this may be desirable for an isolated unit, for laboratory use or for several units working different materials it is not the usual case.

In applying steam, it is possible by a simple arrangement of valves to provide for circulation of cooling water through the ports of the platens. A similar chilling cannot be obtained practically in the case of gas or electricity. Here the work must be moved to a second unit for this operation, which requires that molds for alternate heating and chilling must be portable. This limits such molds to a relatively small size, which may be handled manually.

In convenience of installation, electrical heating is by far the most desirable medium, since the absence of piping is an advantage. Gas installation requires both an air and a gas line and offers no advantages over steam from this point of view.

Costs may be roughly compared on the basis of average power rates for the particular vicinity. Even allowing a generous overhead charge for the steam plant, such a comparison will generally show that the cost of heating by gas is roughly twice that of steam, while electrical heat is several times as expensive as steam.

From the foregoing it may be concluded that while steam is the most desirable heating medium in general, the convenience of gas and electricity may make their use desirable in a small installation. Here, the higher heating cost is balanced by the possibility of intermittent operation without overhead charge, by individual control, and by flexibility. Within the past few years so-called gas and electrical steam generators have made their appearance. These generators may be applied as individual boilers for each molding unit and provide the advantageous heating characteristics of steam with the convenience of control of gas or electricity.

Pressure Media.

Having observed the difference in characteristics of thermoplastics and thermosetting plastics, the pressure media applicable in the molding process may be considered in more detail. Pressure is applied to the mold in all cases by means of a press, the particular type of which may be governed by the nature of the plastic used.

Thermoplastics ordinarily permit the quickest closing of the mold, since in the extreme they may be preheated to full plasticity before loading. Nominal pressure applied to a mold so loaded may take immediate effect. The greatest resistance to this pressure occurs at final closure of the mold, when any slight excess of material may be allowed to escape through a small clearance space. Such requirements may be met by a unit providing varying pressure and mechanical toggle presses may be used successfully for some classes of work. Providing that the pressure variation is not too great and, even more important, that a definite final pressure may be maintained, such equipment may prove satisfactory. In any case the pressure should follow up the yielding material as it flows, being in no sense applied as a blow, as in a stamping process.

The simplest answer to the pressure requirements, especially when uniform pressure is desired, is found in hydraulically operated press units. In spite of the objectionable hydraulic systems required to operate such equipment, hydraulic presses are generally preferred for plastic molding, especially for thermosetting plastics. The hydraulic unit is inherently simpler than a mechanical press for the same purpose and is especially suitable for a long stroke.

In the molding of thermosetting plastics, since little or no preheating is possible, the material in the mold will sustain the initial pressure until flow begins. While

perhaps not entirely necessary, it is customary to establish at once the final molding pressure, allowing this uniform pressure to follow up the flow. Since the material receives its heat from the mold, the intimacy of contact thus established by the total molding pressure at the outset is an advantage. Mechanical presses are not so generally used for molding thermosetting plastics, and the increasing use of such plastics has been largely responsible for the continued improvement of hydraulic units resulting in the modern molding presses.

For the special process of injection molding, the plastic material is forced from the material cylinder indirectly by hydraulic pressure. Mechanical extruding machines, known as screw stuffers, are used in the formation of rods and tubes but are not applicable to injection molding. The empty mold, initially closed, may be held in any convenient clamping device. While this is frequently a hydraulic press, this is not essential.

In the case of blown goods, the molds used are initially closed, as in extrusion molding, with the difference that the mold is already loaded with the stock to be formed. The press for such a mold need be nothing more than a clamping device sufficiently strong to withstand the internal pressure of air or steam inside the stock.

The foregoing outlines briefly the general molding process for plastic materials and the application of heat and pressure to the plastics, as well as insert molding and preparation of material. To give a better understanding of the details of equipment, the next chapter considers some of the more common plastics in regard to their most important characteristics in molding and in use.

CHAPTER II

THE PLASTICS

Rubber.

Development.—The most obvious natural plastic, and the one of greatest importance to man, is rubber. For over three hundred years this gum was considered merely a curiosity by the white race, in spite of persistent attempts to use it as a water-proofing for clothing. Its lack of utility as a pure gum was due to its inability to withstand even moderate climatic temperature changes. The possibilities of the gum, however, led to investigation and experiment and, finally, after years of repeated discouragement, to the discovery of vulcanizing, in 1839, by Charles Goodyear. This vulcanized rubber did not become sticky when warm or brittle when cold, and thus assumed for the first time a practical importance which it has never lost. It is possible that other natural plastics were molded previous to this time, but they were of so little importance that it may be said that the plastic-molding industry was founded on the molding of rubber goods.

Scientific rubber culture of the past few years has made the Far East the chief source of supply for this gum. This cultivated product is more uniform in quality than the wild rubber previously used and at present constitutes about nine-tenths of the world's annual consumption.

Preparation.—Rubber is obtained from a liquid or latex which exudes from the bark of the tree. In the original and picturesque method of separation the rubber was coagulated by evaporation of the water in a thin

film of latex. The fire which provided the heat for evaporation likewise provided smoke which acted as a preservative for the gum. This laborious hand-paddle method is now confined to the small amount of wild rubber still produced. Modern methods employ acetic acid as a coagulant; after coagulation, the rubber is washed, dried, and smoked for an average period of twelve days.

The pure rubber gum, as mentioned previously, is of little use in the production of finished articles and must be combined with one or more ingredients to possess the desired properties. This compounding is carried out in mixing or kneading machines, the most important addition being sulphur, without which vulcanizing is impossible. The amount of sulphur added depends upon the elasticity desired in the finished article. A proportion of 10 per cent by weight is sufficient for soft-rubber goods, while increasing amounts up to 40 per cent produces harder products. For the harder products inert mineral materials may be added as diluents or fillers. By the proper selection of filler, the nature of the finished product may be regulated as desired, some fillers increasing the heat or electrical resistance, others the tensile strength. Coloring pigments are added during this compounding when desired. For the production of hard-rubber goods chemical accelerators are available which, compounded with the mass, reduce the curing time required for vulcanizing the rubber. Thus prepared for the molding process, the mass represents an intimate mechanical mixture of the various ingredients, the sulphur as yet having no effect on the rubber.

Molding.—In molding this material, a temperature must be employed sufficiently high to permit the sulphur to combine with the rubber. The temperature for soft-rubber compounds is commonly 285° F., while the corresponding pressure is 350 to 1000 lb. per square inch. A

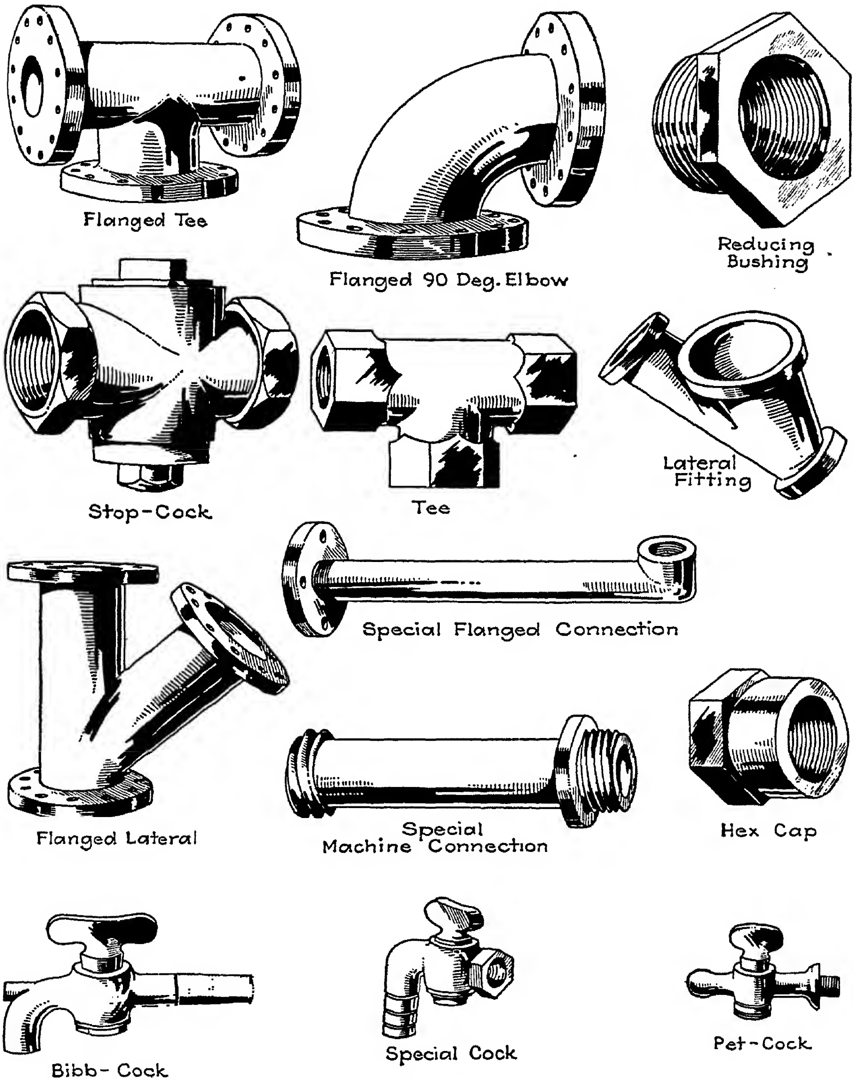

FIG. 6.—Hard-rubber moldings particularly desirable in the chemical plant. Standard and heavy rubber pipe and fittings, carried in stock, are suitable for 50 to 75 lb. pressure. (*U. S. Rubber Co.*)

pressure of 1200 to 1800 lb. per square inch on the material is required in the case of hard rubber, at a temperature of 300 to 350° F. This pressure is sufficient to squeeze out the excess material loaded in the mold to insure complete filling.

The time required for vulcanizing, or curing, varies greatly, depending upon size, shape, and the particular ingredients of the product. A soft-rubber article requiring perhaps half an hour for cure would probably require six to ten hours when produced as hard rubber, with no chemical aids. Proper accelerators may reduce this lengthy cure to one or two hours. Articles of small size may be produced in hard rubber, with as little as twelve to fifteen minutes' cure. Quick-curing hard-rubber compounds now available are the direct result of research stimulated by other plastics with a relatively quicker curing time and have been developed especially for the molding industry. The slower curing compounds may be employed when special properties in the product are imperative, but only the quickest curing rubber compounds may be considered as on a competitive basis with other plastics.

In the molding of soft-rubber goods little effort is spent toward exact measurement of the mold charge. The simple type of mold used is loaded with a generous excess of material to insure filling, and the work may be stripped from the molds without chilling. The molds are not only of a simple type but relatively crude when compared with those required for rigid moldings, frequently being of cast iron, hand-finished. In the molding of hollow goods, the material is roughly shaped before being placed in the mold. A hollow needle is sometimes employed to introduce compressed air into the article during molding, to force the stock to the shape of the mold. At other times, carbonate of ammonia placed inside the stock will generate sufficient gas pressure

during the molding operation to produce a similar result.

In the molding of hard rubber, which is more comparable to the other plastics, the stock may be loaded without preheating into molds of the type previously mentioned. When the time of cure, however, is unusually long, the work formed in cast iron or steel molds may be completed in a steam bath, or it may be transferred to soft molds, such as type metal, for final cure. Such soft molds may be recast as often as desired, at no great expense, which reduces the number of more expensive hard-metal molds needed. From the standpoint of accuracy and operation, such molds are as crude as those used for soft-rubber goods and are hardly to be compared with the fine steel molds used in other branches of the molding industry. In attempting to compete with other plastics, molded to close limits, it may be found that the quick-curing rubber compounds lately developed are molded with equipment much more refined and precise than was formerly permissible. Some of these compounds approach the thermosetting type of plastic in molding characteristics and may be removed from the mold while still hot. In general, hard-rubber products require chilling before ejection to insure against distortion.

The molding properties of rubber are such as to make it one of the simplest plastics to handle. In the one case, its extreme flexibility makes removal from the mold a simple matter, while in the case of hard rubber, proper mold design, taking advantage of the great shrinkage of the material, provides equally easy ejection of finished work. With the length of cure required, exact time control, while desirable, is not so important as with some other materials. Similarly, a considerable degree of latitude in temperature control is permissible.

Chief Characteristics.—The physical properties of rubber are such that its field has never been encroached

TABLE I.—HARD RUBBER[1]

Molding qualities	Fair
Molding-temperature range, ° F.	285–350
Molding-pressure range, lb. per square inch	1200–1800
Specific gravity	1.12–1.40
Specific volume, cu. in. per pound	20–25
Tensile strength, lb. per square inch	1500–10,000
Elongation, per cent	30
Compressive strength, lb. per square inch	2000–5000
Impact strength, Izod	0.5
Modulus of elasticity, lb. per square inch $\times 10^5$	3.3
Hardness, 2.5-mm. ball, 25-kg. load, depth in $\frac{1}{200}$ mm.	31
Thermal conductivity, 10^{-4} cal. per second centimeter degree centigrade	8.7
Specific heat, cal. per degree centigrade gram	0.33
Softening point, ° F.	150
Water absorption, per cent of weight in 24 hr.	0.02
Electrical resistivity, surface, at 50 per cent relative humidity, ohms	10^{12}–10^{15}
Breakdown voltage, 60 cycles, volts per mil	250–900
Dielectric constant, 60 cycles	2.8
Dielectric constant, radio frequencies	3.0
Power factor, radio frequencies	0.9

Colors: Opaque and translucent. Solid black, brown, and red commonest.

Heat: At 150° F. hard rubber softens perceptibly.
At 212° F. it is soft enough to be easily bent.
At 240° F. becomes leathery and is readily cut.
At 390° F. melts.

Burning rate: Medium.

Sunlight: Discolors and disintegrates after a few months. The sulphur is oxidized, forming the equivalent of sulphuric acid. This may take up ammonia from the air, or it may attack the filling material and form various sulphates on the surface. The surface resistivity is greatly reduced.

Age: Deteriorates slowly but if properly vulcanized and protected from light, is not affected.

Ultra-violet light for 20 hr.: Discolors and disintegrates; the action is as pronounced for a few hours' exposure as for months of sunlight; the surface resistivity is greatly reduced.

Moist air: Hard-rubber compounds except those containing organic substances other than rubber are practically moisture-proof.

Steam: The only effect is that due to high temperature.

Solvents: Acetone: Attacks dissolving oils and free sulphur.
Alcohol: Attacks to a slight degree.
Ammonia: No effect.

[1] Courtesy of U. S. Rubber Co.

TABLE 1.—HARD RUBBER.—(*Continued*)

Aniline: Softens at ordinary temperatures.
Benzene: Softens at ordinary temperatures.
Carbon bisulphide: Dissolves small amount of hard rubber and any free sulphur.
Ether: Dissolves small amount of hard rubber and any free sulphur.
Naphtha: Softens and swells slightly.
Oil of turpentine: Dissolves in boiling oil.

Oil: Mineral: Slight softening.
Organic: Unaffected.

Weak acids: No effect.

Weak caustic alkalis: No effect.

Stronger acids (HNO_3, HCl, H_2SO_4): Not attacked by concentrated hydrochloric, hydrofluoric, acetic acids; not attacked by sulphuric acid of less than 1.50 specific gravity, or nitric acid of less than 1.12 specific gravity.

Stronger caustic alkalis: No effect.

Ozone: Oxidizes and soon ruins for electrical purposes.

Metallic inserts: Rapidly deteriorated by contact with iron or copper, the metals themselves being corroded; the inserts should be coated with tin, paper, unvulcanized rubber, or other mutually protecting media.

Machining qualities: Admits of high polish; machines less accurately than would be supposed, due to great resiliency; the better the grade the more readily machined; quality may be judged roughly by color and texture, toughness, and grain of shaving; has tendency to warp.

upon, except in the production of rigid articles. Thus its elastic properties apparently cannot be obtained in any other natural gum procurable in quantity or on a comparative price basis. The only rival substance, synthetic rubber, is not as yet economically a competitor. Where resistance to acids, alkalis, or vibration is important, even the hard-rubber products have not been seriously displaced by newer plastics. Its nonhygroscopic and electrical insulating properties are much in its favor, as well as the fact that it may be produced with a good surface finish and may be easily machined. In the field of mechanical parts, hard rubber may be found lacking in strength in comparison with other plastics. Shrinkage is not only high at the time of molding, but

may persist for an indefinite period. This, combined with warpage, especially in thin sections, tends to exclude hard rubber from the field of accurate machine parts. Of less importance is the tendency of sulphur to come to the surface of hard rubber, with age, giving a greenish appearance to an otherwise black article.

Most rubber compounds lend themselves to the injection process, but molding is seldom done in this way, as the core-covering problems, which might be cared for by injection molding, may be solved by the more general method with less equipment. Hard-rubber products may be recognized under a great variety of trade names, chief of which, perhaps, are Vulcanite, Ebonestos, and Ebonite. The specific properties of the last material are given in Table I, as being typical of good-quality hard-rubber products.

Shellac.

Development.—While natural resins other than rubber have from time to time been used as a base for molding compounds, shellac is by far the most important of this group, owing to lack of supply, lack of desirable molding properties, or high price of the other resins. No definite date can be assigned to the introduction of shellac as a plastic, but it is known to be one of the earliest plastics, if not the earliest, used. It is most probable that some molding of shellac preceded the introduction of rubber, but its industrial growth, in a smaller way, parallels that of the rubber industry. Not having the unique elastic properties of rubber, its field has naturally been smaller from the outset.

Preparation.—In considering shellac as a molding material, it is apparent that the resin alone is of little practical application for molded parts. Not only is the cost of the pure resin prohibitive for such use, but many properties are lacking which may be obtained by com-

pounding with other materials. The shellac obtained as chips or flakes is ground to a powder in a ball mill. The product thus obtained is then mixed with diluents or fillers, such as talc-clay, wood flock, common rosin, and wax. This operation generally takes place dry and at room temperature and is followed by a more thorough incorporation on warm mixing rolls, where the mass is worked in a plastic state. Coloring pigments may be added during either mixing operation, and other fillers may be used with, or in place of, those mentioned, mica being frequently added to increase electrical insulation.

Since the resin in any compound of this sort is merely a binder, there is a definite minimum of resin which may be used with a particular filler. Not only must the particles of filler become coated with the resin during molding, but there must be sufficient resin present to fill the voids to insure the products being nonporous and to present a smooth surface on the finished article. A satisfactory mixture for general use, employing a clay filler, is one part shellac to three parts of filler, while with extensive use of rosin, the proportion of shellac may be as little as 5 per cent. The batch of material as mixed is ready for use, except that as a matter of convenience in handling it is generally run through blanking rolls. These rolls deliver the material in a strip marked off by grooves at proper intervals so that after cooling the strip may be broken up into slabs of regular size.

Molding.—Shellac compounds are characterized by the speed and ease of manipulation. The slabs previously prepared are generally brought to a plastic state on a steam table, convenient to the operator. In this condition it is a simple matter for the operator to select approximately the proper amount for each mold charge. The unavoidable excess may be remolded. It is advisable that the material be preheated only at the same rate at which it is being used, as a sustained preheating tends

to take the life out of the compound. The most common molding temperature is 240° F., and the corresponding mold pressure is 1000 to 1200 lb. per square inch on the material. As there is little or no chemical change demanding a definite temperature for reaction, shellac compounds may be molded over a wide temperature range, requiring a higher molding pressure, of course, at the lower temperature. While the figures given represent average practice, shellac compounds as a

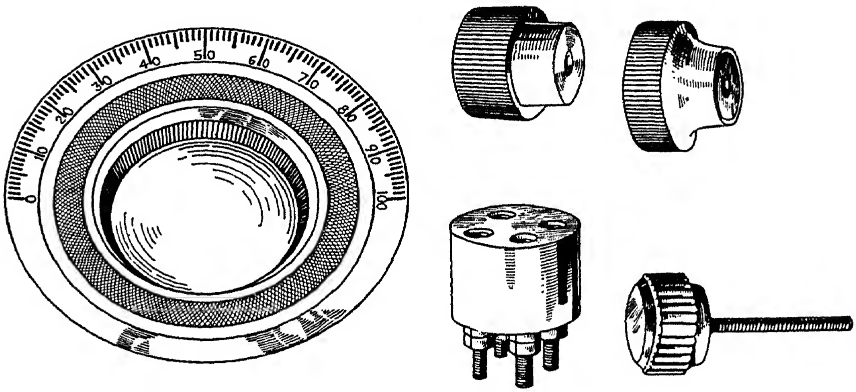

Fig. 7.—Radio parts. Typical application of shellac compounds. Parts may be produced with very good surface finish, and material is good electrical insulator. (*Waterbury Button Co.*)

whole probably offer more latitude in variation of temperature and pressure, than any other plastic.

In molding, shellac compounds are generally preheated to sufficient plasticity to require no further heat from the mold and are thus ordinarily loaded into molds warmed to a nominal temperature, and there chilled to shape. Where sufficiently rapid operation of equipment is possible, the material, well preheated, may be loaded into a cold mold. The molding and chilling operations thus become one, the compound retaining plasticity long enough to take the required shape while cooling at the same time.

Chief Characteristics.—Shellac compounds have other properties beyond speed and ease of manipulation which may make them desirable. The cost of shellac goods is generally low, and the parts may be produced with a high surface polish. The electrical insulating properties are very good, and mechanical strength is fair at normal temperatures. Since the softening point of the material is relatively low, shellac products are not so suitable in heat-resistant capacity as some other plastics and for

TABLE II.—SHELLAC COMPOUND[1]

Molding qualities	Excellent
Molding temperature, ° F.	240
Molding pressure, lb. per square inch	1000–1200
Specific gravity	1.1–2.7
Specific volume, cu. in. per pound	10–25
Tensile strength, lb. per square inch	900–2000
Softening point, ° F.	150–190
Breakdown voltage, 60 cycles, volts per mil	100–400

Colors: Opaque, dark, preferably black; light colors possible.
Effect of heat: Softens.
Burning rate: High.
Effect of age: Warps badly in thin sections.
Weak acids: Decomposes.
Strong acids: Decomposes.
Oils: Decomposes.
Solvents: Alcohols.
Machining qualities: Poor.

this reason have been displaced in such applications. Where such heat resistance need not be considered, shellac compounds may continue to be used in competition with other plastics. As an example of the successful application of shellac compounds may be mentioned the production of sound records for musical reproduction. Other plastics applied in this field have not until very recently encroached upon the use of shellac or displaced it as the chief material for this purpose. Shellac compounds are not suited to the blowing process, but may be readily injected. However, as in the case of rubber,

[1] Courtesy of The Waterbury Button Co.

the general method of molding is preferred as a matter of simplicity in equipment. Likewise, as in the case of rubber, thin, unsupported sections have a tendency to warp with age, precluding the use of such material for precision parts of this general character.

No particular trade names are associated with shellac products, and molding compounds probably vary more in composition than those of any other plastic.

Table II presents the very limited data available for shellac products, based upon a compound containing shellac, rosin, mica, talc-clay, and wood flour.

Pyroxylin.

Development.—This material, known under various trade names as Celluloid, Pyralin, etc., was introduced, upon its discovery in this country in 1868 by John W. Hyatt. This man, a printer by trade, was in search of an ivory substitute for billiard balls, hoping to win a substantial prize which had been offered. While he did not receive the prize, the material which he incidentally produced has been of much greater use than that for which he sought.

Cellulose, the basis of this material, occurs in nature, in almost unlimited quantities, in the form of plant life. Thus wood, stalks, stems, and grass are all potential pyroxylin, being cellulose with considerable extraneous matter, while cotton is almost pure cellulose. This latter is the principal raw material now used, the linters, or short fibers, of little value in textiles being a desirable and economical source of supply for pyroxylin. The other raw material, camphor, has been the natural product until recent years when, owing to uncertainty of supply and fluctuation of price, the synthetic product was adopted.

Preparation.—In the preparation of pyroxylin the cotton or cellulose is nitrated in a bath of combined

sulphuric and nitric acids. After thorough washing, the nitrated cellulose is dried by centrifugal wringing and by absorption of moisture by alcohol. After complete dehydration, fresh alcohol is added, to act as a vehicle for the camphor. These three ingredients, the nitrocellulose, camphor, and alcohol, are thoroughly mixed in a kneading machine after removal of excess solvent. Following this, the batch is worked for 20 to

Fig. 8.—A very satisfactory application of pyroxylin is in toilet goods as shown above, and in toys and novelties. The infinite color possibilities of this material make it particularly desirable for such uses.

50 min. on heated rolls of the same type as used in rubber compounding, until the resulting plastic mass is a thorough combination of the ingredients. The material may then be baked for several hours, under heat and pressure, into a block or slab, which may be sheeted or otherwise cut up for use. If rods or tubes are to be produced, the pyroxylin may go directly from the mixing rolls to extruding machines. In either case, as thus prepared, the stock may be used directly, or it may be seasoned for some time to allow evaporation of excess solvent. This latter and more common procedure may

require from a few weeks to many months, depending upon the hardness of stock desired and the shape and volume of material being seasoned.

Molding.—In molding, pyroxylin is characterized by its adaptability to all the separate processes of forming plastics, by the cleanliness required in handling, and latitude of control of temperature and pressure. For ordinary solid work, especially when the molds are relatively shallow, sheet stock may be stamped, to give blanks of the approximate shape of the finished article. Being a thermoplastic, preheating is advantageously employed and may be accomplished by means of a steam table located near the molding operator. In the case of very thin stock, immersion in a hot-water bath is sometimes sufficient, since the material begins to soften at about 180° F. and for many purposes is not injured by such a bath.

The usual molding temperature is 240° F., which represents a safe maximum limit for average molding, although the material may at times withstand 250° F. before breaking down. The extreme molding pressures, depending upon the temperature, are in the neighborhood of 1000 and 4000 lb. per square inch. For a temperature of 240° F., a pressure of 1800 is sufficient. While the stock may be preheated, it is relatively less plastic than a shellac compound at the same temperature, requiring more pressure and more time to flow. It is therefore the practice to load the stock into at least a nominally warm mold and to supply heat during the molding operation. Chilling is required in all cases to insure permanent shape.

Pyroxylin may easily be forced into a mold by injection. As with other plastics, this is seldom, if ever, advantageous in the formation of solid objects but may be employed in certain cases of core covering. Originally, the method was developed to save the cost of mate-

rial of a solid object, by permitting the use of an outer layer of plastic over a relatively cheaper core of wood or other material. With the present status of material and labor costs, the economy of the method in general is doubtful. On the one hand, it is quite possible to cover cores by the more general molding method when such cores may be required for strength, while where this latter is not necessary, blown goods may be an alternative. On the other hand, when the material may be produced as an enamel or lacquer, as pyroxylin, the articles may be covered by dipping or spraying—a thin covering then sufficing. It has been demonstrated that core covering in general may be done more uniformly by the injection method than by the general molding method, but unless unusually precise requirements are to be met, the latter is to be preferred.

Pyroxylin is particularly well suited to the special process of blowing. In one case tube stock is placed in the mold, which is initially closed. Live steam introduced in the tube produces sufficient plasticity so that the attendant pressure may force the material outward against the walls of the mold. Heating of the mold is arbitrary, but since chilling of the stock is required, this may be done either by chilling of the mold or by circulation of cold water through the blown tube. At times, both have been used to advantage. Since during blowing the mold must be held in its initially closed position, only nominal pressure is required to counteract the internal steam pressure.

As a matter of economy, the use of tube stock for blowing has been displaced, where possible, by flat-sheet stock. In this case, two sheets of stock are placed between the halves of the mold, extending slightly beyond the mold cavity all around. Moderate pressure of about 500 lb. per square inch pinches the stock together at the edges and seals against the internal

pressure of the compressed air used for blowing. Air of 90-lb. pressure is ordinarily used and is introduced at one point between the edges of the stock by means of a hollow needle. With sufficiently warmed molds and preheated sheet stock, no heating is required during the blowing operation. After the work is formed, but before chilling, a higher pressure of 1500 lb. is applied to the stock in order to cut off the excess material and to weld the edges of the blown work. The required chilling may be accomplished by spraying cold water directly on the mold since the bronze molds used are not harmed by this practice.

Chief Characteristics.—The uses for this material are too numerous to mention here, but it is interesting to observe that, almost coincident with keen competition of newer plastics for molding purposes, pyroxylin has found an entirely new and large field in the production of safety glass. As a plastic for novelties pyroxylin has always been in demand, owing to ease in molding and unlimited color possibilities essential to such goods. The material may be readily machined with woodworking equipment and any scrap may be reclaimed. Being generally used without a filler and thus homogeneous throughout, a polished surface may always be restored as originally, by polishing. A number of effective cements are available for joining separate parts, thus allowing building up the finished article or repairing breakage with a more effective fusion of the parts than is generally obtainable.

The relative flexibility of the material is generally in its favor as a guarantee against destruction by fracture, when used for novelty goods. The same property is generally a disadvantage in regard to accurate machine parts, as well as the shrinkage of the material, which not only is high at the time of molding but persists in lesser degree indefinitely. While the mechanical strength

TABLE III.—PYROXYLIN[1]

Molding qualities	Very good
Molding temperature, °F	190–220
Molding pressure, lb. per square inch	2000–5000
Specific gravity	1.35–1.60
Specific volume, cu. in. per pound	17–20
Tensile strength, lb. per square inch	4000–10,000
Elongation, per cent	5–30
Impact strength, Izod	10–11.5
Modulus of elasticity, lb. per square inch $\times 10^5$	2–3.9
Hardness, 2.5-mm. ball, 25-kg. load, depth in $\frac{1}{200}$ mm	45–65
Thermal expansion, 10^{-5} per degree centigrade	12–16
Thermal conductivity, 10^{-4} cal. per second centimeter degree centigrade	3.1–5.1
Specific heat, cal. per degree centigrade gram	0.34–0.38
Softening point, °F	160–195
Electrical resistivity at 30° C., 10^{10} ohms per cubic centimeter	0.106–0.32
Breakdown voltage, 60 cycles, volts per mil	300–780
Dielectric constant, 60 cycles	7.3–6.7
Power factor, 60 cycles, per cent	6.2–14.4
Dielectric constant, radio frequencies	6.8
Power factor, radio frequencies	7.4–9.7
Refractive index No	1.5

Colors: Opaque, translucent, transparent; color possibilities unlimited.
Effect of heat: Material softens, decomposes at 100° to 150° C.
Burning rate: Very high.
Effect of light: Discolors and becomes brittle under ultra-violet light.
Effect of age: Becomes slightly harder.
Effect of water: Swells slightly in hot water.
Weak acids: No effect.
Strong acids: Decomposes.
Weak alkalis: No effect.
Strong alkalis: Decomposes.
Solvents: Alcohol, ketones, esters.
Machining qualities: Good.

[1] Courtesy of *Chemical and Metallurgical Engineering*.

is fair, the material is not suitable in a heat-resistant capacity as the softening point is relatively low. Whereas the scrap from shellac molding may be readily reworked with the compounding equipment usually available in such molding plants, pyroxylin scrap requires more equipment. Since pyroxylin molding plants ordinarily do not make their own material, the scrap is a

serious consideration. To reduce this to a minimum, the material must be formed or blanked to the proper shape and amount to charge the mold. Although this material may readily be extended with fillers of various sorts, this is seldom done in the case of pyroxylin, beyond the pigments sometimes used. In many cases the demands for transparent or translucent stock even require the use of aniline dyes rather than solid-color pigments.

Pyroxylin materials may be recognized under a great variety of trade names, the most important of which are Celluloid, Amerith, Pyralin, Viscoloid, Fibreloid, Xylonite.

Phenol-formaldehyde Resins.

Development.—The greatest single factor contributing to the recent rapid growth of the molding industry was the introduction, some twenty years ago, of a synthetic resin resulting from the reaction of phenol and formaldehyde. Previous to this time, the industry had experienced a continuous but slow expansion, the three thermoplastics rubber, shellac, and pyroxylin having, in the main, been applied in their present-day capacities. This new material, first successfully produced by Dr. L. H. Baekeland and probably more easily recognized under its various trade names of Bakelite, Durez, and others, offered a combination of properties not found in the materials previously used, which greatly extended the field of rigid molded parts. Not only was the industry greatly stimulated by the introduction of this new material and its ready acceptance by the general public, but the equally remarkable growth in research of synthetic resins has had a further effect in the discovery or perfection of other materials introduced since that time. Approximately two thousand United States patents have been taken out in the past twenty years, in the field of

synthetic resins alone. There were practically none before that time.

Preparation.—The resin is produced by the reaction of phenol (carbolic acid) and formaldehyde, in the presence of a catalyst. Since incidentally water is also formed during the reaction, the material is frequently referred to as a condensation product. The reaction is carried out in a digester, heat being required to start the operation, after which, the heat generated is usually more than sufficient to continue the change. A thin, amber-colored fluid occurring during the first part of the reaction, may be run off, to cool and harden in open molds. This resin in pure form finds some limited use in imitation amber products but is not used for ordinary molding purposes. During the latter part of the process, and before reaction is complete, a similar but heavier fluid may be obtained which will likewise harden on cooling. This is the resin used for molding and is actually the product of an uncompleted chemical reaction which, however, is later completed in the molding operation, producing a hard, infusible material.

As prepared for use, the hardened resin in the cooling molds is broken up and worked into the selected filler on warm mixing rolls. This batch, after thorough mixing and cooling, is ground to a powder ready for molding. The filler acts as a diluent for economy and also imparts properties not inherent in the resin alone. While special fillers, such as mica, asbestos, canvas scraps, and others, may be used, wood flour is the commonest material for the purpose. Varying proportions of filler and resin may be employed, depending upon the use of the finished article, but 25 per cent resin represents about the practical minimum in compounding with wood flour.

Molding.—In molding this compound, it is loaded into heated molds, without preheating, since the nature of the

material does not permit of this to any great extent. When sufficient heat has been absorbed at the proper molding temperature of 350° F., the resin becomes plastic. Not being thermoplastic, softening does not occur so soon with a rising temperature but takes place more definitely at the molding temperature. The

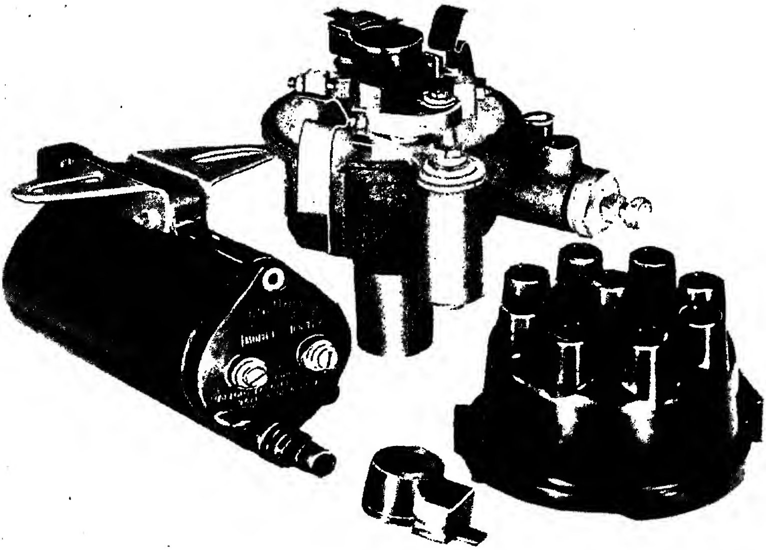

FIG. 9.—Automobile parts of "Durez." The infusible phenol-formaldehyde compounds are well suited to electrical insulation and mechanical uses. While for general use the resin is mixed with wood flour, special compounds may be employed having asbestos, fabric, or mica filler. (*General Plastics, Inc.*)

full molding pressure initially applied to the loaded mold is sustained by the material until plasticity occurs. Then the pressure follows up the yielding material, until the mold closes, after which the material is held under heat and pressure for a short time to allow the compound to cure, or set. Since upon curing the material is hard and infusible, the work may be ejected without fear of deformation, and the usual chilling operation may be omitted, allowing the molds to be kept con-

tinually heated. Higher molding pressures may be used for special compounds employing unusual fillers, but 2000 lb. per square inch may be considered standard for wood-flour mixtures.

The bulky powdered material may be loaded directly into the mold without special preparation. The handling and measuring of such material are generally a slow, inefficient process and require very deep and therefore more expensive molds, since the bulk reduces in the ratio of at least 2½ to 1 during molding. The powdered material may be compacted under a blow of 4 to 6 tons per square inch, and hence a tableting machine is used in almost all cases to prepare the material for loading.

Chief Characteristics.—Phenol-formaldehyde products are characterized by their relative permanence, due to the infusible nature of the material and its hardness. Thus, while the material can be destroyed by high temperature, it has relatively high heat resistance, and deformation at moderate temperatures does not occur. Also, while the mechanical strength and electrical insulating properties are very good, these qualities, combined with the small amount of shrinkage, permit the use of the material for accurate mechanical and electrical parts. While preheating is ordinarily not feasible, the relatively quick cures and elimination of chilling permit of high production. The molded products, being infusible, do not permit of reworking, except by use as a filler for new material and after being ground. The cost is generally higher than that of new filler. However, the slight overflow, or excess, expelled during the molding operation, being incompletely cured, may be subsequently used if reground and extended with new material.

The original brown and black compounds have been augmented by many attractive colors, permitting a wide

choice in plain colors and in mottled and striated effects. The molded material may be machined. Especially in drilling, the operations have been greatly improved with the introduction of cutting tools especially suited to the material.

Being applicable to the production of mechanical parts, increasingly greater demands have been made in the accuracy of such work. The primary result of this has been such an improvement in design and construction of molds as to practically establish a new standard in mold building. A secondary, and perhaps more apparent, improvement has likewise come about in the press equipment used to operate these newer molds. The combined improvement in equipment, together with quicker-curing materials, has resulted in production never before attainable. The importance of the equipment developed chiefly owing to this plastic makes it the main consideration in the subsequent chapters on this subject, while the older and less refined equipment is given brief mention.

While this material is not suited to molding by the blowing process, it has, within recent years, been successfully formed by injection molding. The cases requiring such treatment are relatively few and very special. The practice has not been established long enough to have standardized details of equipment, although the injection pressures first used, varying from 10,000 to 30,000 lb. per square inch, have been successfully reduced to the approximate value of 6000 lb., the temperature remaining at 350° F. The products tend to have somewhat less mechanical strength than those produced by the more general method.

The compounds used for this special process are particularly soft, or full-flowing, the resin being at an earlier stage of reaction than that used for general molding. The claim is occasionally made that injection-

molded products have greater strength than those produced by the general method. The evidence indicates that this may be the case if the material is particularly

TABLE IV.—PHENOL-FORMALDEHYDE COMPOUNDS[1]

	Wood-flour filler	Asbestos filler	Fabric filler
Molding qualities	Excellent	Fair	Good
Molding temperature, °F	350	300–330	300–330
Molding pressure, lb. per square inch	2,000	2,000–2,500	3,000–3,500
Compression ratio	2.5	2.5–7	8
Specific gravity	1.36	2.05	1.39
Specific volume, cu. in. per pound	20.4	13.5	20
Tensile strength, lb. per square inch	9,000	6,000	8,000
Compressive strength, lb. per square inch	32,000	32,000	32,000
Impact strength, ft.-lb. per square inch	2.3	1.75	21.0
Modulus of elasticity, lb. per square inch $\times 10^5$	13	43	11
Mold shrinkage, in. per inch	0.007	0.002	0.006
Thermal conductivity, 10^{-4} cal. per second centimeter degree centigrade		16	
Specific heat, cal. per degree centigrade gram	0.35	0.35	0.35
Heat resistance, °F	300	500	300
Water absorption, per cent by weight 24 hr.	0.31	0.015	0.68
48 hr.	0.5	0.045	1.3
144 hr.	1.4	0.12	2.5
Electrical resistivity, megohms per cubic centimeter	2.5×10^5	1×10^5	0.4×10^5
Breakdown voltage, volts per mil	350–500	275–400	300–450
Dielectric constant, radio frequencies	5.54	5–20	5.0
Power factor, radio frequencies, per cent	4.31	6.0	5.0
Dielectric constant, audio frequencies	6.25		
Power factor, audio frequencies, per cent	7.25	15.0	14.0

[1] Courtesy of The Bakelite Corpn.

well cured. Weak moldings are probably chiefly due to attempting too great a rate of production.

Phenol-formaldehyde molding compounds appear under a great variety of trade names, among which are Bakelite, Durez, Norloc, Nobeline, Bexite, Nestorite,

TABLE V[1]

	Pure hardened resin	Laminated	
		Paper filler	Fabric filler
Molding temperature, ° F.		250–325	250–325
Molding pressure, lb. per square inch		1,000–2,000	1,000–2,000
Specific gravity	1.2–1.3	1.3–1.4	1.3–1.4
Specific volume, cu. in. per pound	21–23	20–21	20–21
Tensile strength, lb. per square inch	5,000–11,000	6,000–20,000	8,000–12,000
Impact strength, Izod	0.5–2.5	5–25	10–65
Modulus of elasticity, lb. per square inch × 10^5	10–25	5–20	5–15
Thermal expansion, 10^{-5} per degree centigrade			
Thermal conductivity, 10^{-4} cal. per second centimeter degree centigrade	3–4	5–8	
Specific heat, cal. per degree centigrade gram	0.33–0.36	0.3–0.4	0.3–0.4
Water absorption, 24 hr., per cent	0.05–0.07	0.2–1.0	0.2–2.0
Electrical resistivity, 10^{10} ohms per cubic centimeter	1–100	1–10	0.1–1.0
Breakdown voltage, 60 cycles, volts per mil	250–700	500–1,300	200–600
Dielectric constant, radio frequencies	4.5–7.0	4.5–6.0	4.5–7.0
Power factor, radio frequencies, per cent	0.5–5.0	1.5–5.0	2–8
Refractive index, N_D	1.56–1.70		

Colors: All opaque, except pure resin which may be opaque, translucent, or transparent. All colors possible. Most common in natural and dark shades.

Effect of heat: Slight hardening and shrinking. Electrical properties improved. Will withstand 250° F. continuously.

Burning rate: Very low, asbestos-filled material practically incombustible.

Effect of light: Lowering of surface resistivity from ultra-violet light.

Age: Improves mechanical and electrical properties.

Water: Slight deterioration after long immersion in hot water.

Weak acids: Practically no effect.

Strong acids: Decomposes.

Weak alkalis: Slowly softens.

Strong alkalis: Decomposes.

Metallic inserts: Inert.

Machining qualities: Fair; in general requires metal-working tools.

[1] Courtesy of *Chemical and Metallurgical Engineering*.

Textolite, Micarta. The last two are particularly shock-resistant materials, having a fabric filler, while the others, as general-purpose materials, are commonly filled with wood flour.

Table IV gives the properties of three typical molding compounds. The general-purpose material has a wood-flour filler. The heat-resistant mixture is compounded with asbestos. The shock-resistant material carries a fabric filler in the form of scraps of linen or canvas. This latter is not to be confused with laminated stock as listed in Table V. The general characteristics accompanying Table V apply equally well to the materials listed in Table IV.

Casein.

Development.—Although casein is a material by no means new, its application in the molding industry was rather late in this country and lagged far behind its more general use in France and Germany. Whereas the material was largely imported when first used here, it is now being produced in increasing quantities, incidentally having uses other than molding.

The common source of commercial casein is cows' milk, and essentially it is the precipitate, or curd, resulting from the souring of skimmed milk. As a product of the natural reaction the casein is actually cheese and as such contains such impurities as butter fat, sugar, and acid, which make it unfit for molding purposes.

Preparation.—As prepared for the trade, skimmed milk is treated with a solution of rennet after removal of excess butter fat by centrifugal wringers. The action of the rennet is to precipitate the casein, or curd, allowing the liquid, or whey, to be drained off. After repeated washings in pure water, the casein is dehydrated under pressure, then ground, and thoroughly dried. A second process employing dilute acid instead of rennet is used,

but the casein thus produced is generally inferior in quality for molding but suitable for other uses. As ordinarily prepared for the molding trade, the casein is supplied in rods or tubes, formed by extrusion, or in sheets or slabs made up from an aggregate of rods.

Casein does not attain the degree of plasticity required to make it as full flowing as many other materials, and for this reason many small articles are produced from rod and tube stock by machining. In this capacity it may be shaped readily with wood-working equipment, especially in turning.

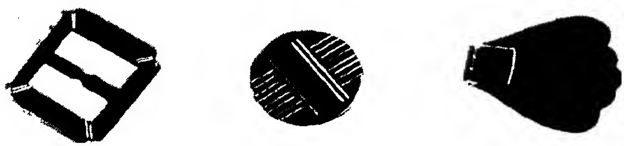

Fig. 10.—The casein parts shown have been blanked out from sheet stock and have been finished by machining. While a very limited type of molding may be done with casein, the material is generally considered not moldable. Two-tone color effects are produced by surface-dyeing the article and subsequently carving. (*American Plastics Corp.*)

Molding.—In the field of molding, the material is best suited to relatively shallow molds, for which it may be prepared by being blanked out to approximate size and shape. The blanks may be preheated in a liquid bath at about 200° F., or between steam platens. Since casein is hygroscopic, softening in hot water, although convenient and sometimes done, is inadvisable. The preheated and softened blanks may be placed in the mold and held under pressure until chilled to permanent shape. The process is closer to so-called die pressing than the fabricating of most plastics. After removal from the mold, the material may require any or all of the subsequent operations of dyeing, water-proofing, buffing, or machining.

Chief Characteristics.—Since the shrinkage in casein products is considerable, this material is not particularly suited to the production of mechanical or precision parts but finds its chief use in novelties. In this field it has a great variety of color effects possible for the production of attractive goods at a relatively low price. While as a molding material casein does not have an extensive field, it has made a place for itself beside the older and established plastics and may be expected to continue as a competitive material in the manufacture of novelties.

Casein is marketed under a variety of trade names, including Erinoid, Galalith, Karolith, Aladdinite, Secalite, and others.

TABLE VI.—CASEIN[1]

Molding qualities	Poor
Molding temperature, ° F.	200–225
Molding pressure lb. per square inch	2000–2500
Specific gravity	1.35
Specific volume, cu. in. per pound	20.5
Tensile strength, lb. per square inch	7600
Impact strength, Izod	1.0
Modulus of elasticity, lb. per square inch $\times 10^5$	5.07–5.7
Hardness, 2.5-mm. ball, 25-kg. load, depth in $\frac{1}{200}$ mm.	23
Thermal expansion, 10^{-5} per degree centigrade	8.1
Electrical resistivity, 10^{10} ohms per cubic centimeter	11.4
Breakdown voltage, 60 cycles, volts per mil	400–700
Dielectric constant, radio frequencies	6.15
Power factor, radio frequencies	5.19

Colors: Unlimited, translucent, and opaque.
Effect of heat: Swells in moist heat.
Burning rate: Nil.
Effect of light: None.
Effect of age: None.
Effect of water: Absorbs.
Weak acids: No effect.
Strong acids: Decomposes.
Weak alkalis: Softens.
Strong alkalis: Decomposes.
Machining qualities: Good.

[1] Courtesy of *Chemical and Metallurgical Engineering* and other sources.

Urea-formaldehyde Resins.

Development.—Among the later synthetic resins to be introduced in the industry are the condensation products of urea and thiourea with formaldehyde. The urea resins first introduced about 1926 were not entirely successful, owing to the difficulty of molding. This temporary setback stimulated further research which not only materially improved the original resin but also

Fig. 11.—Tableware in colors. Particularly attractive in pastels. Material—the original thiourea "Beetle." This material is both odorless and tasteless. (*Beetleware Corp.*)

disclosed the thiourea product. This second resin was in some respects superior to the first but at that time difficult and expensive to produce. At the present time both resins are produced on a favorable price basis, and improved control in manufacture has led to a uniform product in each case.

Molding.—The urea compounds may be molded at pressures ranging from 2000 to 3000 lb. per square inch. The pressure recommended is 2500 lb. or more. The molding temperature may vary from 275 to 300° F. The

reduction in volume in molding from bulk is about four to one; hence the material is generally tableted. Ground paper is the filler commonly used. The length of cure required in molding is about 50 per cent more than with phenolic compounds, and the completeness of cure is very important as the product is otherwise not fully resistant to water. A special feature of operation is the gassing which these compounds require. This is accomplished by a slight reopening of the mold after its initial closure and by subsequent closure for final cure.

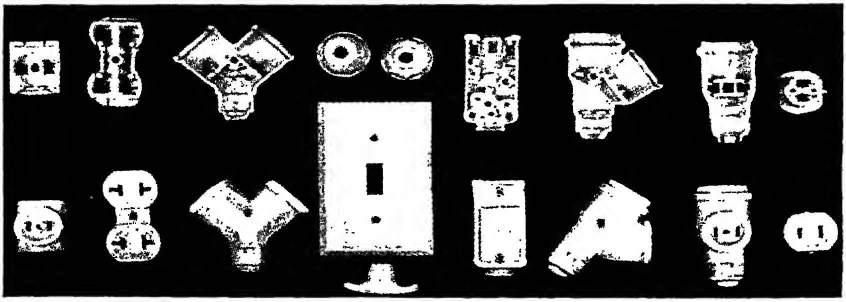

FIG. 12.—Electrical properties and light-color possibilities allow the use of urea material for cream-colored fixtures shown here. Material—Beetle. (*Beetleware Corp.*)

Chief Characteristics.—The molded material may be readily machined and, although not so flexible as pyroxylin products, is nevertheless not brittle. The tensile strength ranges from 5000 to 7000 lb. per square inch, and the material is resistant to alcohol, oil, acetone, and common solvents. It is attacked by hot acids or hot alkalis. Practically all color effects are possible and are particularly pleasing in pastel shades used in thin sections, owing to the translucence of the product.

The thiourea resin is generally blended with the urea product, rather than being used by itself. The filler used in compounds is ground paper. The general characteristics of the molded material are very similar to

those of urea products. The temperature range in molding is 280 to 300° F., while the molding pressure required is 4000 lb. per square inch. Being thermosetting, either compound may be only moderately preheated. The urea products may be molded in the usual steel molds, a trace of sulphur in the thiourea compounds making stainless-steel molds desirable for this latter material.

The urea compounds are the most recent plastics to have been adopted commercially and are marketed under such trade names as Plaskon, Aldur, Unyte, and Beetle.

TABLE VII.—UREA-FORMALDEHYDE COMPOUNDS[1]

Molding qualities	Good
Molding temperature, ° F.	275–300
Molding pressure, lb. per square inch	2,500–3,000
Compression ratio	4
Specific gravity	1.48–1.50
Specific volume, cu. in. per pound	18.5
Tensile strength, lb. per square inch	5,000–7,000
Compressive strength, lb. per square inch	24,000–26,000
Transverse strength, lb. per square inch	9,000–13,000
Impact strength, ft.-lb. per square inch	2.0–2.3
Mold shrinkage, in. per inch	0.006
Water absorption, 24 hr., per cent	0.6–0.9
Breakdown voltage, 60 cycles, volts per mil	300–400
Dielectric constant, 60 cycles	7.0
Power factor, 60 cycles, per cent	1–3
Refractive index No	1.6

Colors: Opaque, translucent, and transparent. Unlimited color possibilities. Pastel shades particularly beautiful.
Effect of heat: Shrinks slightly. Will swell in moist heat.
Burning rate: Very low.
Effect of light: None.
Effect of age: None.
Effect of water: If completely cured, no effect up to 30 min. in boiling water.
Weak acids: No effect.
Strong acids: Decomposes.
Weak alkalis: No effect.
Strong alkalis: Slight effect.
Machining qualities: Fair.

[1] Courtesy of The Synthetic Plastics Co.

The last may still be obtained in its original thiourea composition which for special purposes is in some respects superior to the urea products. For general use, however, the material distributed under this name is now a urea product. As ordinarily supplied, the material is in a powdered or granular form which may be tableted.

Table VII presents the chief properties of Beetle, which may be considered typical of the better materials of this entire group.

Cellulose Acetate.

Preparation.—While cellulose acetate is by no means a new material, its relatively high cost has until recently prohibited its use for molding. It may be manufactured from cotton linters or other cellulose, as in the case of pyroxylin. The treatment in this case requires acetic acid, acetic anhydride, and a catalyst, such as sulphuric acid. While the process is more difficult to control than that for producing pyroxylin, it is chiefly improvement in this particular which has finally placed cellulose acetate on a favorable cost basis.

Molding.—The product, resembling pyroxylin, may be used in practically any similar capacity. It may be used in tube or sheet form, for blowing, or may be extruded easily, since it is thermoplastic. For general molding it is generally prepared in powdered form and used with little or no filler beyond the pigments used for coloring. The material may be preheated before molding, transparent stock softening at 140 to 150° F. and pigmented stock at 160 to 180° F. The molding temperatures are 275° F. for transparent stock, or 300° F. for the pigmented material. The molding pressure in either case may be 2000 lb. per square inch. Being thermoplastic, the material requires chilling before ejection.

Chief Characteristics.—The molded material has a tensile strength of 2800 to 3600 lb. per square inch for

transparent stock, and 3000 to 4200 lb. for pigmented products. The electrical insulating properties are very good. Chemically, the material is attacked by acetates and by strong acids and alkalis. While desirably strong and flexible, the material does not have so high a resistance to heat as the thermosetting plastics, although in this respect it is superior to pyroxylin and shellac

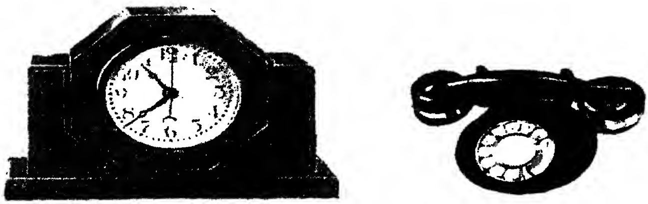

FIG. 13.—The great color possibilities of cellulose-acetate equal those of pyroxylin, while in being almost non-inflammable, it has a greater field of application than the older material. Parts shown are of "Lumarith." (*Celluloid Corp.*)

goods. In comparison with pyroxylin, its chief point of superiority lies in its heat resistance, as there is otherwise little practical difference in the two materials. With difficulty cellulose acetate may be burned, but it is ordinarily considered noninflammable.

While not essentially a new material, cellulose acetate has only recently entered the commercial molding field. In this application many new names have appeared within the past five years, among which are Lumarith, Plastine, Celastine, Sicoid, Celastoid, Bexoid, and Rhodoid. These materials may be obtained in the form of sheets, rods, tubes, slabs, chips, or powder. The last, permitting tableting, is the commonest form for molding purposes.

Conclusion.

As regards the foregoing tables of properties of plastics, it may be expected that values for specific compounds

may vary from those tabulated here. The figures given, however, are fairly representative of each group, although the methods of testing are unfortunately not completely standardized at the present time.

For more detailed information relative to the properties of some of the older materials, the reader may refer

TABLE VIII.—CELLULOSE ACETATE[1]

	Transparent	Pigmented
Molding qualities	Excellent	Excellent
Molding temperature, ° F.	275	300
Molding pressure, lb. per square inch	2,000	2,000
Compression ratio	2.4	2.4
Specific gravity	1.29	1.56
Specific volume, cu. in. per pound	20.5	17.8
Tensile strength, lb. per square inch	2,800–3,600	3,000–4,200
Compressive strength, lb. per square inch	4,000	11,000
Transverse strength, lb. per square inch	6,300	7,000
Impact strength, ft.-lb. per square inch	3.2	2.2
Modulus of elasticity, lb. per square inch $\times 10^5$	1.47	2.61
Hardness, 2.5-mm. ball, 25-kg. load, depth in $\frac{1}{200}$ mm.	45–65	45–65
Thermal expansion, in. per inch per degree centigrade	0.000156	0.000102
Mold shrinkage, in. per inch	0.0025	0.0045
Thermal conductivity, 10^{-4} cal. per second centimeter degree centigrade	5.4–6.3	5.3–8.7
Specific heat, cal. per degree centigrade gram	0.43	0.36
Softening point, ° F.	140–150	160–180
Water absorption, 48 hr., per cent	1.9	1.4
Breakdown voltage, volts per mil	590	470
Dielectric constant, 60 cycles	8.4	12.0
Power factor, 60 cycles, per cent	7.7	15.3
Dielectric constant, radio frequencies	4.3	4.9
Power factor, radio frequencies, per cent	5.7	5.9
Refractive index, N_D	1.49–1.50	

Colors: Opaque, translucent, and transparent. Unlimited color possibilities.
Effect of heat: Material softens.
Burning rate: Very low.
Effect of light: Slight embrittlement and discoloration from ultra-violet light.
Effect of age: Very slight hardening.
Effect of water: Swells, especially when warm.
Weak acids: Slightly affected.
Strong acids: Decomposes.
Weak alkalis: Slightly affected.
Strong alkalis: Decomposes.
Solvents: Acetone, amyl and methyl acetates, ethyl lactate, essential oils, diacetone alcohol, chlorinated hydrocarbons with alcohols.
Machining qualities: Good.

[1] Courtesy of The Celluloid Corporation.

to U. S. Bureau of Standards data, or to the "International Critical Tables." More recent and complete compilations may be found in the *British Plastics Yearbook* of 1931, and in the December, 1932, issue of *Chemical and Metallurgical Engineering*.

Credit may be given the American Society for Testing Materials for considerable standardization in the testing of plastics. The reader is referred to the report of Committee D-9 of this society, relative to *Electrical Insulating Materials*. This report (1932) on methods of test gives method, procedure, and equipment, as well as sizes and shapes of standard test specimens.

While the present chapter covers the most common plastics, these represent a very small proportion of the known materials. Concurrent with the work done on phenolic materials and stimulated by the success of this first thermosetting plastic, a great deal of research has been done in plastics. Roughly two thousand United States patents have been issued in this field, practically all of them within the last twenty-five years. The result of this has been perhaps 350 new materials. Many of these, not suitable for the general molding field, have found application in other capacities.

Some attempts have been made to develop materials having a low molding temperature but subsequent high heat resistance. Other efforts have aimed at the elimination of press equipment through use of a material requiring little or no pressure to mold. Neither line of endeavor has met with measurable success, and it may be expected that in the future the methods and equipment for plastic molding will remain substantially as at present.

An idea of the variety of trade names and materials in the industry, may be gained from Table IX (see Appendix), listing plastic products and producers.

PART II

MOLDS

CHAPTER III

TYPES AND USES

Introduction.—As a general introduction, and particularly in the interest of those unfamiliar with molding equipment, the present chapter is limited to a consideration of elementary mold types and their uses. For the sake of clarity as regards types, incidental structural features relating to the style of the mold are purposely omitted here and separately considered in the following chapter. Similarly, details of design are not considered here but are treated at length in subsequent chapters. For the present, the principle of the various mold types is the feature of importance, and no more than this is presented in the simple illustrations shown.

Classification of Mold Types.—If consideration is limited to the physical action of the plastic during molding as determined by the design of the individual mold cavities, a logical and simple basis for classification may be established. On this basis only four distinct types of molds may be found: flash, positive, injection, and blowing. The first two of these are particularly of interest as applying to the general molding process. The remaining two, while important in their respective fields, are limited to special uses.

In addition to the distinct flash and positive molds, there are a number of composite types sufficiently important to warrant consideration. Owing to the close relationship, these are presented immediately following the flash and positive types, leaving the more special injection and blowing molds until last.

Flash Molds.

Characteristics.—Flash molds are distinguished by the feature of design which permits excess molding material to escape directly during final closure of the mold. This slight excess, purposely included with the mold charge, is used to insure complete filling of the mold and as expelled during molding is referred to as overflow, or flash. By such a method of loading, slight and unavoidable variations in density of the mold charge become inconsequential, and extreme precision in the measurement of the charge is eliminated. This in turn permits economies in the preparation of the material, whether tableted or otherwise. A second distinct characteristic of this type of mold is the absence of sliding parts, with consequent absence of wear of the mold cavities.

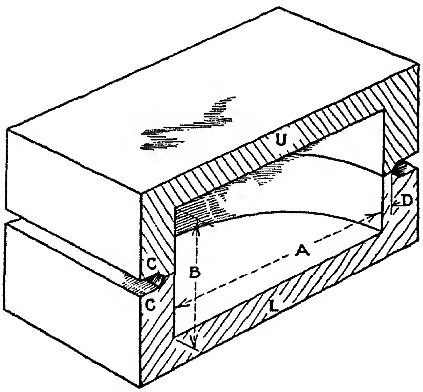

FIG. 14.—Flash mold.

Figure 14 illustrates the principle of a flash-type mold, showing a section through the upper and lower dies, *U* and *L*, of a single mold cavity. For simplicity of explanation, the piece to be molded is assumed to be a disk of diameter *A* and thickness or height *B*, one-half of the piece being formed by each die. The surfaces otherwise in contact when the mold is closed are relieved, providing a clearance or overflow space at *C*, into which the flash may escape. The portion of contact surface retained is a strip of width *D*, extending completely around the cavity and called the flash, or cut-off surface. It is between these approaching flash surfaces that the

excess material must flow during final closure of the mold, leaving a thin fin on the molded piece to be later removed. The removal of this fin may be of great importance, constituting practically the only finishing operation required in the majority of cases. Minimum finishing is attained by proper proportioning of the flash surface. For a given mold pressure a narrower flash surface provides a thinner and more easily removed fin, with the extreme or minimum thickness dependent upon the crushing strength of the dies.

As distinct from some other types of molds, it may be observed that the total height of the cavity *B* is no greater than that of the molded piece. This inherent characteristic of flash molds in general allows them to be built of minimum total thickness and, more important, of minimum weight. This is a distinct advantage in case the molds are to be alternately heated and chilled or are to be manually handled during molding. While the saving in cost of metal in the mold is inconsequential, the manufacturing cost of this type of mold, owing to its simplicity, is appreciably less than that of other types. Similarly, owing to the absence of sliding parts, the length of life is greater and the maintenance is less than with other mold types.

Use of a flash mold as shown in Fig. 14 generally presupposes that the molding material has a density approximately that of the molded piece. Thus the mold charge is to be not only of the required weight to form the piece, but its bulk should be little more than the volume of the molded piece. Otherwise a compression of the material is required, which is seldom obtainable in a flash mold, since the material is not completely enclosed when first loaded and may easily escape. For this reason, while many plastics are suitable for use in flash molds directly, materials in a bulky powdered form require special consideration. Obviously the solution

is to tablet or preform such materials and apply the simple type of mold shown here.

Where tableting of bulk material may be impossible because of the nature of the compound, or inadvisable owing to the special and unusual shape of the molded piece, the application of the flash mold is very limited. Figure 15 illustrates a variation of the usual design, which may be applied in special cases. Cup-shaped moldings particularly fall in this field of possibility and are here illustrated by a cup of diameter A and height B. For such pieces, the cut-off surface may be placed at the top of the molding as shown, permitting the top die U to be a flat plate, carrying an attached male force C for forming the inside of the cup. The advantage of this design is in the depth B, in the lower die, which in many cases provides sufficient volume in this die to accommodate all the bulky loose material when first loaded. Provided that sufficient flat surface is presented by the force C, the loose material under it, while partially compressed on initial operation of the mold, will sustain the total molding pressure until the material becomes plastic.

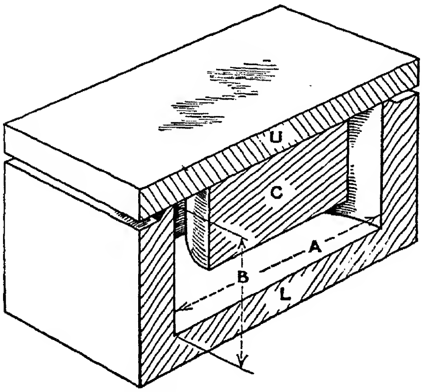

FIG. 15.—Flash mold. Cut-off at top.

The possibility of applying this alternative design of flash mold obviously depends upon the proportions of the cupped molding and upon the compression ratio of the bulk material. Pieces requiring thin bottom and side walls represent the most favorable conditions in permitting a minimum of material to be accommodated

in the lower die. Since, however, the compression ratio of bulk materials may vary widely, it is apparent that such a mold designed to accommodate a relatively dense powder may be entirely unsuitable for use with a lighter material.

Uses.—Fortunately the conditions requiring molding from bulk material are rare, and the usual design of flash mold using tableted material is applicable in the great majority of cases. Since the loading of molds with loose material tends to be a slow operation, molds so loaded are almost without exception excluded from the field of high-production molding. From the standpoint of simplicity, lightness, high production, low first cost, and maintenance, flash molds should be applied whenever possible. Redesign of the molded piece is justified whenever possible in order to avoid the more complicated mold types.

Positive Molds.

Characteristics.—Occasionally it is required to mold a bulky material which cannot be handled in a flash mold, owing to the shape of piece and volume of material before molding. To overcome the objection of the flash mold, the type of mold employed, obviously, must trap the material to prevent its escape when the mold closes. This leads to the distinct type known as a positive mold, which is characterized not only by the initial trapping of the molding material but also by the requirement that it be loaded with exactly the proper amount of material.

Original Design.—Figure 16 illustrates the principle of a true positive mold, for the production of a disk of diameter A and height B. The upper die U is in the nature of a male force or plunger, which slides or telescopes into the lower die ring L. It may be seen that the loose molding material is initially trapped in the lower die ring L, which must be relatively deep. While

the molded work may be removed from a mold of this kind by means of an ejector pin in the lower die ring, it is customary to make the entire bottom a separate piece, as plate *P*. By this means, in raising the mold and removing plate *P*, the work may be pushed downward and out by the upper die *U*.

Two serious drawbacks to this mold are inherent in the design as shown. In one case, whether the work is ejected down or up, it will be marred on the peripheral

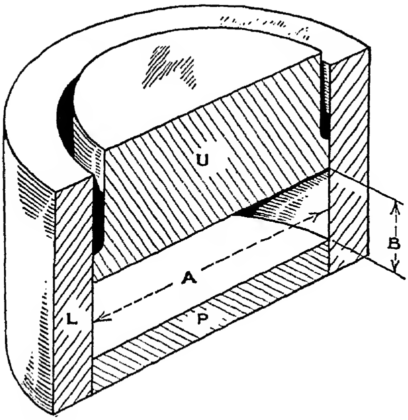

Fig. 16.—Original positive mold.

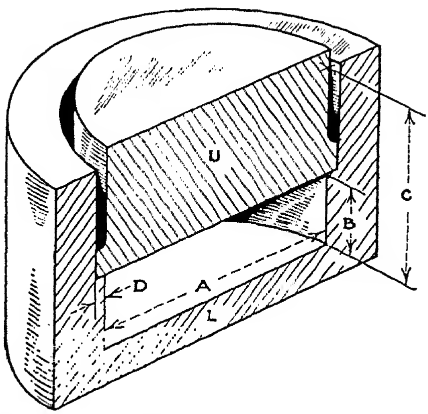

Fig. 17.—Positive mold. Common design.

surface. This arises from the scoring of the wall of the lower die by the plunger and is practically unavoidable, particularly as the mold becomes worn. In the second case, the height of the finished piece is dependent upon the molding pressure and the amount of material in the mold. While the maintenance of a uniform molding pressure is relatively simple, the extreme care required in the measurement of the mold charge for a mold of this type bars its use commercially.

The design of mold shown is occasionally used for laboratory work. For such use, where exact height of the piece may not be of great importance, such a mold

produces pieces of more uniform density than the more common design of positive mold. In such a capacity, slight variation in the measurement of the mold charge is permissible.

Common Design.—In contrast to the true and original positive mold is the commercial design shown in Fig. 17. This design retains the principle of trapping the material but provides for uniform height of a molded piece through use of a land *D* in the lower die ring *L*, which brings the upper die *U* to a positive stop. While at first glance it would appear that any excess of material might be expelled between the plunger and the bore of the lower die, this is not the case. Built to operate in this manner such a mold would be a continual source of annoyance, since the removal of such flash from the deep lower die would be extremely difficult. Hence, measurement of the mold charge is still an item of importance. However, in this case, above the minimum required to fill the cavity a slight excess is permissible, since with sufficient pressure the mold may still be properly closed, and the slight variation in density of the molded work is inconsequential.

It is expected that with proper operation a fin of nominal thickness will be formed on the land under the plunger. This remains with the piece upon removal of the latter and, while not desirable, cannot be avoided. If maintained of the proper thickness, this fin may be easily removed. If, however, an abnormal excess of material is used, it is evident that without a corresponding excess of pressure the height of the molded pieces will vary, and a heavy fin will be formed which may be expensive to remove.

In this design of mold, the work is usually ejected upward. This may be done by means of an ejector pin in the lower die *L*, or by having the bottom made as a separate piece, as shown in Fig. 16. In either case, the

work may be removed without scoring the peripheral surface.

The depth C of the lower die L is, of course, dependent upon the particular molding compound used. The volume of the lower die can seldom be less than twice the volume of the molded piece when using compounds having a wood-flour filler. An average figure for this compression ratio for such compounds is $2\frac{1}{2}$, while in using a shredded fabric filler such as canvas scraps, the ratio may be as high as 8.

In any case, it is evident that a relatively deep and heavy mold is required, which is not only expensive to produce but objectionable from the standpoint of heating and chilling, handling, and maintenance. As may be expected, positive molds are subject to a great deal of wear, and as the original clearance is thus increased, such worn molds are troublesome owing to the continual cleaning required.

Uses.—The characteristics of a positive-type mold being chiefly objectionable, its usefulness may be questioned. Obviously designed for handling loose material, its use can be justified only when such operation is imperative. While such cases are relatively rare, unusual demands may make such a mold desirable in at least two general instances.

In the first, slender pins supported in a horizontal position in the mold may be easily displaced and bent when using tablets. Where such pins are inherent in the design, less deformation may result from using loose material for the molding. A second case may be illustrated by an unusually large single-cavity mold. Added to the impracticability or impossibility of producing a sufficiently large preform for such a mold is the diminished importance of the loading time, since the molding cycle is long, and such molding cannot be considered high-production work. The usual procedure in such a

case is to load the mold with a number of small tablets rather than with the loose material. This practice reduces the depth of mold required and rarely may even permit the application of a flash mold.

Thus, in spite of excessive wear due to sliding parts, greater weight, and higher cost, positive molds are occasionally found to be the logical type to meet some special requirement. Owing chiefly to slowness of loading, molds distinctly positive in type are not high-production molds. Composite molds, however, combining both the positive and flash principles, embody advantages of both types of molds and may be employed for large-scale production.

Semipositive Molds.

Characteristics.—A composite type of mold known as semipositive is illustrated in Fig. 18. In comparison with the positive mold of Fig. 17 it may be noted that the total height of the mold is much less, the depth C of the lower die being little more than the height B of the finished piece. This is made possible by the use of a relatively short plunger on the upper die plate U. In contrast to the positive mold, this plunger has sufficient clearance in the bore of the lower die, so that any excess of molding material may escape. In addition, a flash surface of the same kind as used in a flash mold is provided to act as a positive stop.

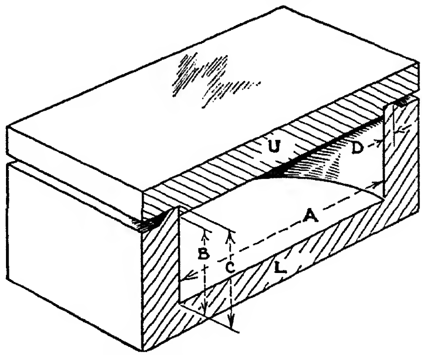

Fig. 18.—Semipositive mold.

Owing to the short plunger used and to the relatively shallow cavity, molds of this type are but little better suited to the molding of loose material than the flash-

type mold. However, loaded with tablets or other dense material the production rate is equal to that of flash molds.

As an advantage for this type of mold it is claimed that the added restraint placed upon the excess material during escape creates a back pressure resulting in a more dense molding than that from a flash mold. Whether or not this difference is great enough to be of any practical importance is not determined. A very real advantage of this mold, however, is in the type of fin produced on the molding. Thus by the proper clearance of the plunger, the thickness of vertical fin may be determined, independent of the thickness of the flash. Whereas for a single cavity this would not appear to be any advantage, nevertheless in molds producing perhaps one hundred or more pieces at one time, a certain amount of variation in thickness of flash may be found in using the ordinary flash mold. Use of a semipositive mold thus provides for proper thickness of fin on molded work and uniformity of this fin on the various moldings. This feature, inherent in this mold, is not characteristic of, and is practically unattainable in, the flash type.

Uses.—Since the initial cost of a semipositive mold is little more than that of a flash mold, selection of this type must be based upon its two particular characteristics. In the first instance, uniformity of fin makes this mold particularly desirable in production work where large multiple-cavity molds are needed. Second, in molding from tableted material which may crush under the initial load free escape of particles of the material may be prevented by the trapping action of the semipositive mold. This applies as well to powdered material, but whereas the short plunger used is effective against crushed tableted material, it has a smaller advantage in the case of bulk material.

Subcavity Molds.

Characteristics.—The subcavity mold was developed to permit rapid loading, when using a loose molding compound in a multiple-cavity mold. The loading time is decreased by use of a single charge of material sufficient to fill all cavities rather than by individual loads. As may be seen in Fig. 19, the general appearance of the mold is that of the positive type, having a relatively deep lower die L, while the upper die U is in the nature of a plunger. The depth C must afford sufficient volume in the lower die for the complete charge, which is initially trapped by the plunger. While apparently the action is the same as that of a positive mold, an inspection of the individual cavities shows this is not the case. Even with careful distribution of the initial mold charge some of the cavities are unequally filled. Upon becoming plastic, however, the material is extruded from the overfilled cavities, making up this deficiency. The individual cavities, then, are essentially flash molds, the flash surface between cavities depending upon the thickness D left between them. Whereas with moldings of a rectangular outline, this surface may be a minimum, it is advisable to stagger the cavities when they are circular or irregular in plan, in order to keep this flash surface within reasonable limits.

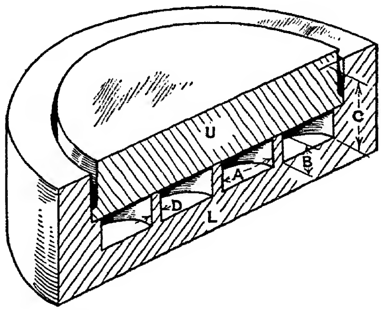

FIG. 19.—Subcavity mold.

Uses.—Since the tableting of powdered material has become a common practice, the subcavity mold is of much less importance than formerly. However, it may still be the proper type for the production of many very

small parts, since in this case the loading time may be less than if using tablets. Of the various types of molds suitable for molding powdered material, the subcavity design is the only one which may be considered capable of high production.

Floating-chase Mold.

Characteristics.—The principle of a floating-chase mold is illustrated in Fig. 20. This mold is essentially a double-acting positive type and was primarily designed for the production of articles with a vertical height relatively great compared to the plan dimensions. In justifying this type of mold it may be observed that when the usual design of positive mold is applied to moldings of this general shape, the density of the molded piece varies considerably from top to bottom. In extreme cases, the material may not even completely fill out the mold at the bottom, owing to the dissipation of pressure above. In some cases this may be satisfactorily overcome by increasing the molding pressure by a given amount depending upon the depth of the mold, while rarely the work may be most effectively handled in a floating-chase mold.

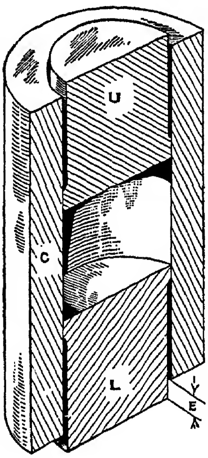

FIG. 20.—Floating-chase mold. Original design as shown, without land.

In this mold the work is pressed from both top and bottom by the plungers *U* and *L* guided in the chase *C*. Since the chase is free to float or find its position of repose with respect to the friction of the material in the cavity, the same molding pressure is applied at both the top and bottom of the piece. The variation in density is thus reduced to 50 per cent of what it would be in a simple positive mold of the same depth.

For proper operation of the mold it is important that the chase be given clearance in height E, so that the platen surface supporting either plunger cannot transmit pressure to the chase. It is equally important that the plunger L be somewhat retracted (or the chase raised) when the mold is loaded, so that there will be equal amounts of material above and below the center of the chase. The chase is usually supported during loading to permit this, but it is not restrained during the molding operation.

As shown, the floating-chase mold is of the original positive design and is open to the same objections as regards exactness of loading and pressure requirements. For commercial application the same alteration in design is used as in the case of the positive mold. Thus a land provided for each plunger insures uniform height of the molded work. As in the simpler case this defeats to some extent the principle of a positive type of mold in permitting a slight variation of density of the product, but for practical purposes it is inconsequential.

Uses.—Although this mold was developed primarily for powdered molding compounds and is of less importance when tableted material is considered, it can be equally well applied in the latter instance in extreme cases. Obviously, when deep, the simple shape shown in Fig. 20 could most easily be produced if molded with the axis horizontal, and this is to be preferred. Special considerations, however, do not always permit such logical choice for the position of molding.

In spite of the floating-chase mold's being distinctly a positive type, it may be considered a very special mold, owing to its limited use. It is heavier than the positive type and more expensive to build. The operation is usually slower, and, being a free member, the chase presents difficulties in heating. If designed for use with tableted material, it may be considerably less bulky,

but at best still represents a type of mold essential to one purpose but otherwise to be avoided.

Stripper-plate Mold.

Characteristics.—A variation of the flash-type mold distinctive enough to warrant mention is the stripper-plate mold shown in Fig. 21. The lower die L is a deep die of the usual flash design and the upper die consists of two parts, a male force or plunger U, and a plate S carrying the upper-flash surface. In a modern molding unit, U and S may be operated independently of each other, S and L being brought into contact, with the plunger retracted. The effect of this is to initially trap the molding material in the lower die, after which the descending force U acts in the nature of a displacement plunger, forcing out the excess material. This design precludes the possibility of spilling of material before closure of the mold, as may occur in a flash mold. While this is incidental, it is a very desirable feature, whether molding from tablets or from powdered material, although more important in the latter case.

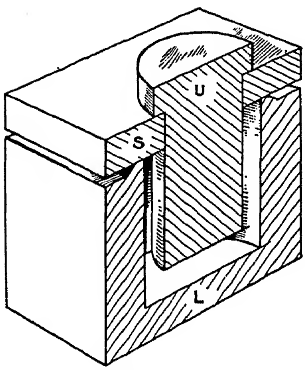

Fig. 21.—Stripper-plate mold.

Uses.—The primary, though perhaps less apparent, function of the mold is to facilitate the ejection of thin-sectioned moldings of cupped shape. In attempting to eject such work from the lower die by means of the customary ejector pins, it is quite possible to punch through the bottom of the molding or deform the bottom. Upon opening the stripper-plate mold, however, parts U and S ascend as a unit, carrying the molded part on the plunger. At the proper point, S may be brought to a stop, while U continues to rise, stripping

the molding from the plunger by pressure of the plate on the rim of the cup.

While this type of mold must be mounted in, and operated by, the press unit, and is appreciably more expensive to build than a flash mold, it is doubly desirable owing to its displacement-plunger operation and effective ejection of work. However, either of its advantages may be desirable by itself, and its application for deep-cupped moldings is especially warranted. Some resemblance may be seen between the stripper-plate and floating-chase types of molds in spite of the fact that they are basically different types and have been developed for different purposes. In the relatively few overlapping cases in which either type may be applied, the stripper-plate mold is to be preferred to the floating-chase type.

Split Molds.

Characteristics.—It occasionally happens that moldings must be produced with undercuts or projections which make withdrawal from a simple two-part mold impossible. In some cases, a simple type of mold may be applied when altered to accommodate so-called loose pieces. Such pieces may either be ejected with the molding and require manual replacing in the mold at each loading, or they may remain with the mold but be retractable through a hand-operated leverage of some sort. Where such expedients are inapplicable, such work may be molded in a three-part or split mold, as illustrated in Fig. 22. The commonest type of piece to which such molds apply is of spool shape carrying an axial hole, as shown in the illustration. The main part, or body, of the mold is split along an axial plane, which is generally vertical. The resulting parts are relieved on the faces in contact, at *C*, much the same as the two parts of a flash mold, except that the remaining surface is

wider and is not used for flash purposes. The third part of the mold is normally a plunger U, for forming the hole in the piece, and is guided in the mold by the lower parts A and B. Where the resulting hole is to extend through the piece, as in the illustration, the plunger may terminate in a tapered pilot, as at E, to eliminate lateral displacement. The plunger U may be shouldered as at D, to provide a positive stop when not extending through the piece.

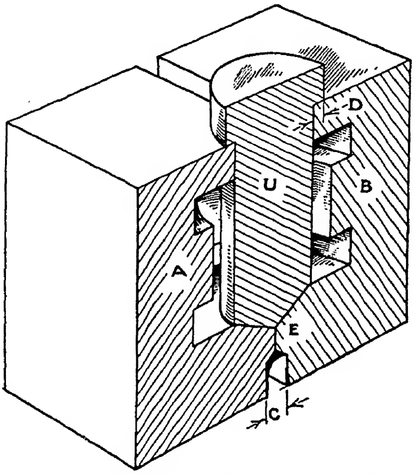

FIG. 22.—Split, three-part or angle mold.

In operation, parts A and B are initially brought together before loading. While they may best be actuated when mounted in a machine designed for the purpose, it is quite possible to hold them together by a clamping device, such as a chase ring. With the plunger retracted, the mold is charged through the plunger-guide hole. The material initially trapped is displaced by the descending plunger. Depending upon the particular application, the mold may be made to act either as a flash or as a positive mold. Parts A and B are not allowed to separate during the operation. Thus, if designed for flash operation, the plunger must have sufficient clearance to allow escape of excess material.

When the plunger U requires a force which is relatively small compared with that required for A and B, it is possible to operate the mold in the usual molding unit. For such operation parts A and B become upper and lower dies, respectively, while the plunger is operated in a

horizontal position by a special auxiliary cylinder, all mold parts being mounted in the machine. When the force required to operate the plunger is approximately of the same magnitude as that for parts *A* and *B*, it is customary to operate the mold in the position shown with a special molding machine carrying the mold parts.

In contrast to such press-mounted split molds are those designed for manual handling. For such operation, parts *A* and *B* are most conveniently made tapered on the outside faces and held together by means of a corresponding tapered case. As may be expected, such molds are not only slow in production but require more maintenance than any other style or type. They are ordinarily operated in the same position as in Fig. 22. The difficulty of heating such manually handled molds and the objectionable features previously mentioned normally exclude them from use except as a last resort.

Use.—In spite of the fact that split molds are not limited to single-cavity design, are not excessive in cost, and may operate at fair speed if press-mounted, they are not met with as frequently as may be supposed. The probable reason for this may be found in the special unit often required for satisfactory operation and which, for lack of special work, may stand idle a great portion of the time. Lacking this special equipment, a great deal of ingenuity is frequently expended in applying special features to the usual two-piece molds to make operation possible in the molding units commonly met with. For the infrequent application of split molds such special features may be justified in spite of the higher mold cost occasioned by their use. Thus while the application of split molds in general is obviously determined by the shape of the piece to be molded, it may be concluded that such molds are most economically designed to operate in special molding units, where the volume of work justifies such installation.

Injection Molds.

Characteristics.—Injection molds are a basic type distinct from either flash or positive molds. They are initially empty when closed, and afterwards the material is forced into them in a plastic condition through a small port or orifice.

Figure 23 illustrates a simple injection mold, consisting of upper and lower dies *U* and *L*. The main surfaces are relieved as at *C*, leaving a land *D* around the cavity, but again, as in the case of split molds, this is normally wider

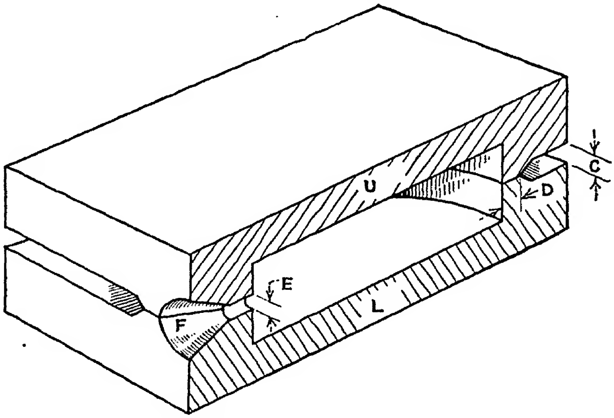

Fig. 23.—Injection mold.

than a flash surface and does not act in the same capacity. The material is forced into the mold through a port of diameter *E* common to *U* and *L*. The taper *F* at the port inlet is to accommodate the nozzle of the extruding machine, from which the material is received.

In the case of thermoplastics, molds of this type are manually handled, and the extruding machine is a separate unit from the press in which the mold is held. Such an extruding machine may carry sufficient material for charging the mold many times, since the plastic will withstand prolonged preheating.

In contrast to this are the new injection-molding machines developed for handling thermosetting plastics. While the mold principle remains the same, the operation is somewhat different. In the first place, the material may be preheated only at the same rate at which it is being used. This limits the extrusion cylinder to a relatively small unit carrying a single mold charge. In addition, it is found advisable to mount the mold in the machine. Such an injection-molding unit combines the separate machines used for thermoplastics into one compact unit. The injection molds used for such molding are generally of a higher class in workmanship than the older style.

Uses.—As to the uses for injection molds, it is apparent from Fig. 23 that simple shapes such as the one shown do not require this special process for molding. However, when plastics were relatively more expensive than at present, it was frequently found desirable as a matter of economy to cover an inert core of foreign material with an outer layer of plastic. Occasionally the added strength of the part still makes the use of such cores desirable, although the economy in molding material is less important than formerly. Since core covering may be done in other types of molds, it follows that such work is not limited to the injection process. However, it may be said that cores may be more evenly and concentrically covered in an injection mold than in any other type. This feature of injection-molding was the chief factor in bringing about a revival of the process and developing a machine for handling thermosetting plastics.

Incidental to handling thermosetting plastics by this process, it has been found that small moldings, complicated in design and delicate in thin wall sections, may be effectively produced in injection molds. This feature in combination with the requirement of slender pins or

wires used as cores may make the choice of this type of mold desirable for special work.

Blowing Molds.

Characteristics.—A fourth distinct type of mold, used solely in the production of hollow goods, is the blowing mold. The blowing process presupposes a chamber of plastic, nonporous material, which may be expanded in the mold by internal pressure. Rubber and pyroxylin

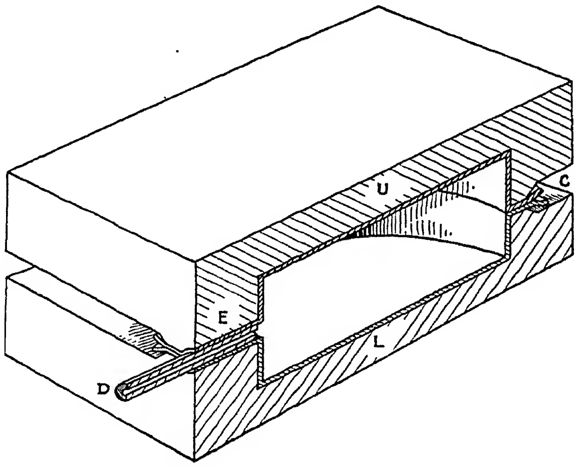

FIG. 24.—Blowing mold. For sheet stock.

are the two materials falling naturally into this special field of molding, and such products constitute the great bulk of all blown goods.

Sheet Molds.—Figure 24 illustrates a simple blowing mold, such as is commonly used with pyroxylin. The material as loaded between dies *U* and *L* is initially flat-sheet stock and is of sufficient size to extend beyond the cut-off surfaces. In this position, the two sheets of stock are pinched together between the cut-off surfaces

by a nominal pressure on the dies. With the stock sufficiently plastic, a tight seal is thus formed, after which compressed air may be admitted between the sheets by means of the nozzle *D* inserted between their edges in the port *E*. The material now properly shaped is welded at the cut-off edge by a mold pressure sufficient to bring the dies together, cutting off the excess stock. The air pressure is maintained until the material is chilled. A light burr resulting from the cut-off generally requires removal by hand as a separate operation.

Uses.—Practically all pyroxylin-blown goods are produced from sheet stock in molds of the sort illustrated. These are usually manually handled, are made of bronze, and in general being designed for toys or art goods do not require the machine work common to other molds. The irregular-shaped cavities are finished by hand and require specially trained die makers, while the casting of the mold itself is a special foundry work. Blowing molds are of a relatively simple type and usually do not conform to the exacting standards of shape and size common to other molds.

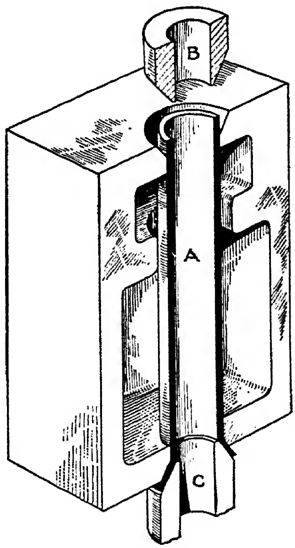

Fig. 25.—Blowing mold. For tube stock.

Tube Molds.—A second, but less important, style of blowing mold employs tube stock for loading. In this mold, shown in Fig. 25, no cut-off is required. The tube *A* is placed in the mold, with its ends projecting through ports common to the two dies. Tapered nozzles *B* and *C* forced into the ends of the tube provide a tight joint for the circulation of steam through the stock. The steam both softens the stock and blows it to shape, after

which cooling water may be circulated through the tube for chilling. Since the mold remains closed during the operation, any adequate clamping device may be substituted for the usual molding unit. Hand-operated screw presses have been used for this work in the past, operating the molds in the position shown. As a matter of economy, the blowing of tubes has been largely displaced by the use of sheet stock, where the visible weld between parts in the latter case is not objectionable.

Rubber Molds.—In the blowing of rubber goods, molds of substantially the same type are used as for pyroxylin sheet stock. Here, however, no cut-off is required, as the stock may be roughly shaped before loading and is enclosed in the mold cavity. The internal pressure for blowing may be obtained by enclosing a small amount of ammonium salt within the article. Heated during the molding operation, this material will generate a gas pressure. Where this is found undesirable, compressed air may be introduced by means of a nozzle. A hollow needle used for this purpose is sufficiently small to allow the puncture to heal by itself, upon withdrawal of the needle from the object.

Conclusion.

In regard to mold type, the shape of the molded piece is generally the determining factor in the type selected. The die or mold cavity is ordinarily designed from a study of the requirements as shown by a drawing or model. Where tolerances are important, the drawing is indispensable, while a model is very desirable in determining, by displacement, the volume of the die cavity. This is of practical use in computation of the expected consumption of molding material and in establishing the size of tablets for the mold.

Fortunately most molded shapes are produceable in either simple flash molds or molds of this general type with no more than slight modification. Frequently, in doubtful cases, an investigation into the intended use of the molded part will show that a redesign of the piece is possible, allowing the use of a simple mold without special features.

CHAPTER IV

STYLE

Apart from basic characteristics of design which, in being individual, determine the type of mold, there are many features which are common to molds in general.

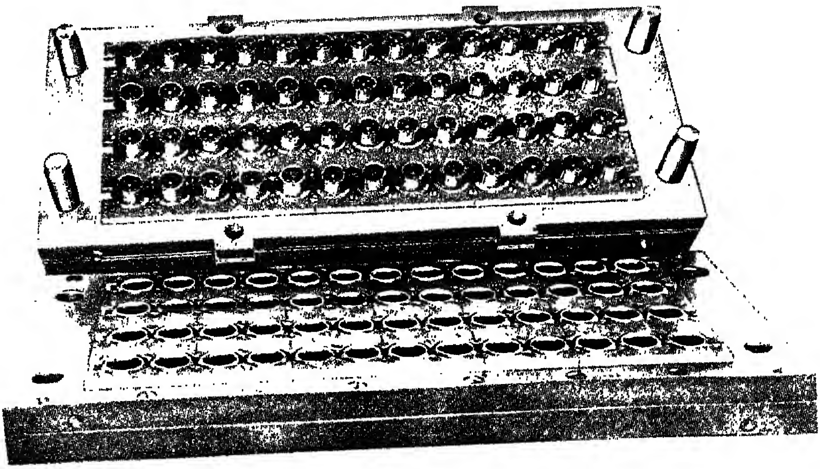

FIG. 26.—Semipositive mold of built-up construction, consisting of heater plates and hobbed dies. Dies are replaceable and may be removed in twos or threes without dismantling entire mold. Mold (15 by 31 in.) requires press mounting for operation. Where molds are continually heated, indirect heating, as here applied, is practically equivalent to direct heating.

These features are here considered referring to the style of the mold. While other items could be included under this heading, only three of most importance are of interest at this time. These refer to (1) the number of cavities, or size of mold; (2) the method of operation; and (3) the method of heating.

Size.

Single-cavity Mold.—As regards the number of cavities or size of mold, it is apparent that a single-cavity mold is not production equipment, since many pieces may be molded in the same time interval as a single piece by using a multiple-cavity mold. Only three cases justify

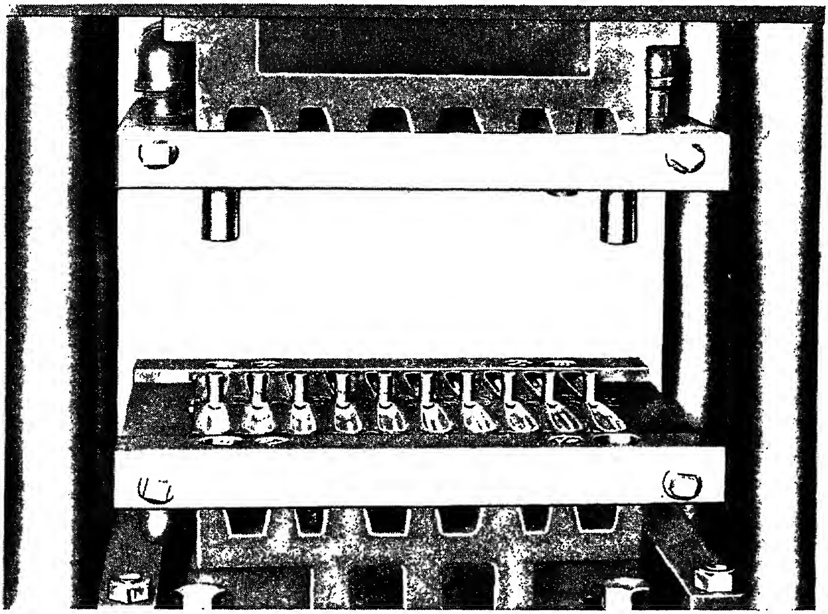

FIG. 27.—Twenty-cavity flash mold. The vertical pin standing between each pair of cavities carries a small horizontal pin for forming a hole in the work. The vertical pins are used as ejectors, lifting the molded parts from the lower dies, on the horizontal pins.

the use of single-cavity molds: First, an unusually small production requirement of a relatively complicated molding, in which the rate of production is secondary and in which the volume of product can absorb only the minimum mold cost. While operating costs and the mold cost per molded piece are relatively high, such work is more or less specialty molding and commands a

higher price than ordinary goods. Secondly, it is quite possible that a molding may be of a size to require the total capacity of a molding unit. Lastly, before undertaking the construction of a large multiple-cavity mold, it is fairly common practice to try out the design in a single-cavity mold. Apart from these few special applications, single-cavity molds find no use in the industry.

Multiple-cavity Molds.—As the industry expands, larger molds are employed, and the conception and standards of production change, making it difficult to classify molds on a basis of size. For the present purpose of illustration, however, arbitrary assumptions may be made in considering a requirement of 10,000 pieces small production; 100,000 average, and 1,000,000 large production work. Correspondingly, multiple-cavity molds designed to produce the same parts in these various classes of production, may have 25 to 50, 50 to 100, and 100 or more cavities, respectively, where the parts are small.

Ultimately, the exact determination of the size of mold required is a matter of economics rather than engineering. This is especially true in the field of small production. If it be assumed that an order for 10,000 parts is to be filled over a definite period of time, at a regular rate, an elementary knowledge of molding cycles will suffice to determine the number of cavities required for this rate of production. Where the parts are small, the resulting mold may be operated in a small molding press. On the other hand, this may not be the most economic solution, since this small mold may not require the full attention of the operator and the labor charge per molding is thus increased. One corrective for this consists of operating two small molds on separate orders in adjacent molding units, overlapping the molding cycles to employ the operator's time more effectively.

As an alternative to this, the mold size may be greatly increased, to require the full attention of the operator. In thus increasing the rate of production, such molds may be operated intermittently to meet the requirements. Where availability of press equipment for

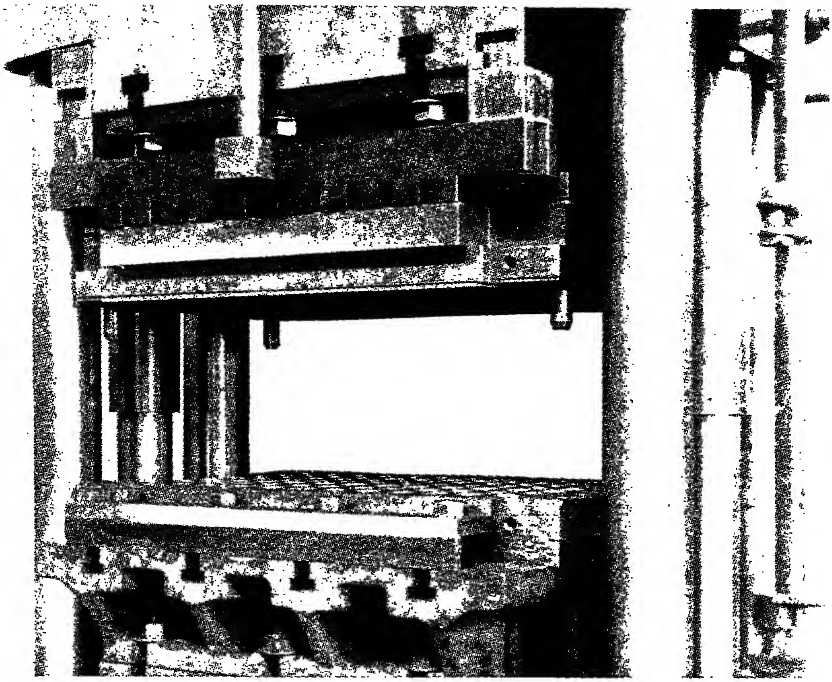

FIG. 28.—Stripper-plate mold (with dies removed.) Note mounting of main mold parts in press, and substantial proportions of parts. Upper plate carrying dowels, as well as plate above, is fixed. Next plate above is movable. Movable plate ejects work from upper dies.

other orders is desirable, this solution may be advantageous in spite of the higher mold cost to be distributed over the product. Determination of mold size in such cases requires an intimate knowledge of equipment facilities, operating and overhead costs.

In addition to these determinable factors are the unforeseen hazards of producing novelty goods. Here the

intangible qualities of style and popularity of product must be considered, with two possibilities in mind. On the one hand, failure of the product results in a large undissolved mold cost, while the other extreme leads to insufficient mold capacity for the unexpected volume of product. Such molding problems properly require the collaboration of both sales and engineering effort and represent the most difficult and unsatisfactory conditions for determination of mold size.

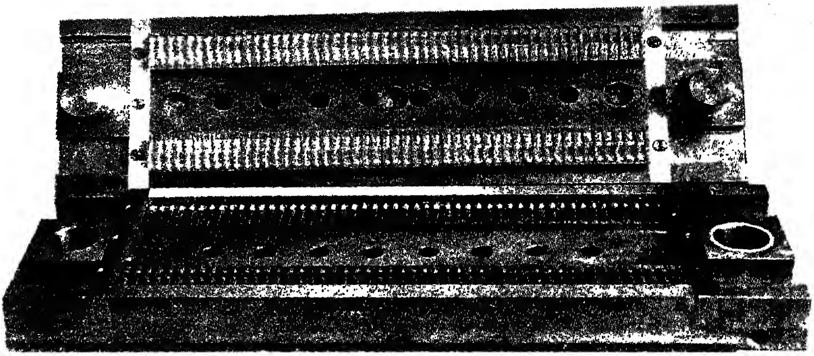

FIG. 29.—One hundred-impression subcavity mold for molding handles on small screwdrivers.

The foregoing applies to a lesser extent to molds designed for larger production. Here, mold sizes are generally such as to require the full attention of an operator, and maximum capacity molding presses may be required for operation. The novelty hazard is generally less in this class of work, and molds are expected to operate continuously over relatively long periods of time. Even in this field, if the plastic is thermosetting and requires a sufficiently long cure, it is sometimes possible to overlap molding cycles on adjacent presses to reduce attendance charges.

For large production, mold sizes are automatically determined by maximum press facilities available, and

several molds of maximum size will usually be required for the work. Such requirements represent ideal operating conditions, permitting minimum charges for set-up where press-mounted molds are used. In addition to this, the mold cost distributed over this large volume of work allows for special operating features or refinements which may reduce labor charges and which are not necessarily economical in small production molds.

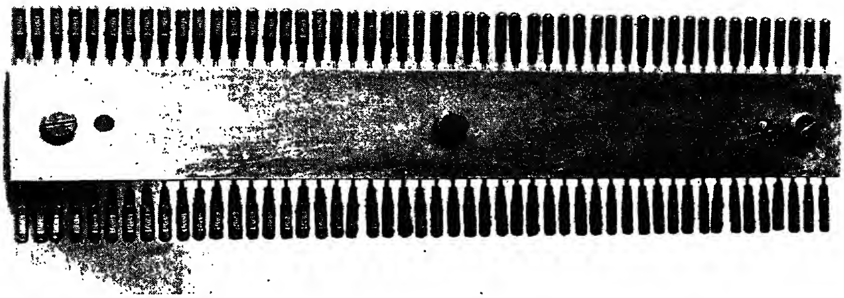

FIG. 30.—Insert-carrying plate for screwdriver mold. Two such plates permit the continuous operation of the mold, with one plate in operation while the other is being loaded. Insert plate also used for ejection.

Operation.

Style of mold, as regards operation, embraces hand-molds, and semiautomatic or press-mounted molds.

Hand Molds.—Hand molds, which were standard mold equipment in the early years of the industry, have been displaced to a large extent since thermosetting plastics have come into wide use. Such molds have the advantages of simplicity, low cost, and almost complete absence of set-up charges in putting them into use. On the other hand, the maintenance of such molds is generally high, owing to the manual handling and incidental abuse to which they are exposed. For large production work, the low first cost is more than offset by

higher operating charges, and such molds are seldom used in this field. In job molding, where the production may be very small, hand molds may still be used to

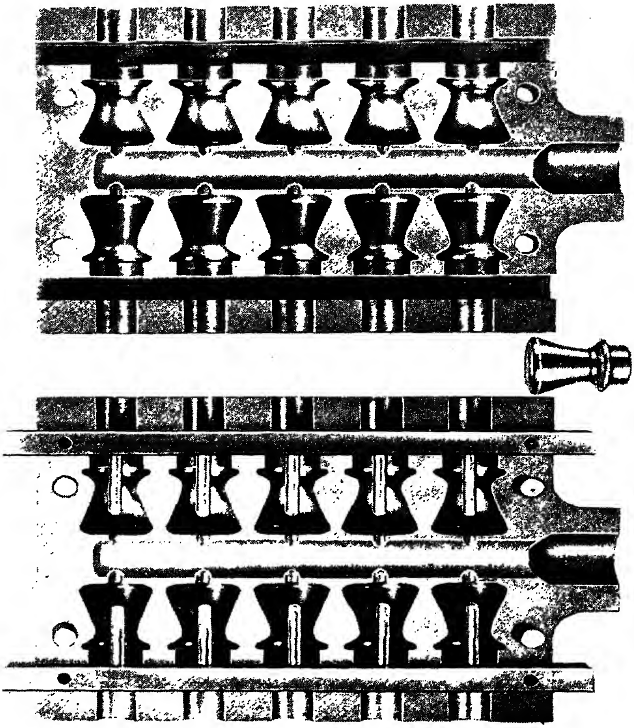

FIG. 31.—Unit-construction hand mold for injection molding of brush handles. Note two shank bars carrying pins, upon which wooden cores are mounted. Note lateral porting, permitting entering plastic to assist in holding core in place.

advantage, even with the newer thermosetting materials. Rubber and pyroxylin molding, originally founded on the use of hand molds, continues largely with this traditional equipment, explainable in part by the small-lot and frequent-change requirements. In size, all such

molds are limited to a practical weight for manual handling which, for ordinary purposes, is 50 lb.

Semiautomatic Molds.—In contrast to hand molds are the semiautomatic molds designed for press mounting, in which the great bulk of the newer plastics is molded. These molds are limited in size only by the

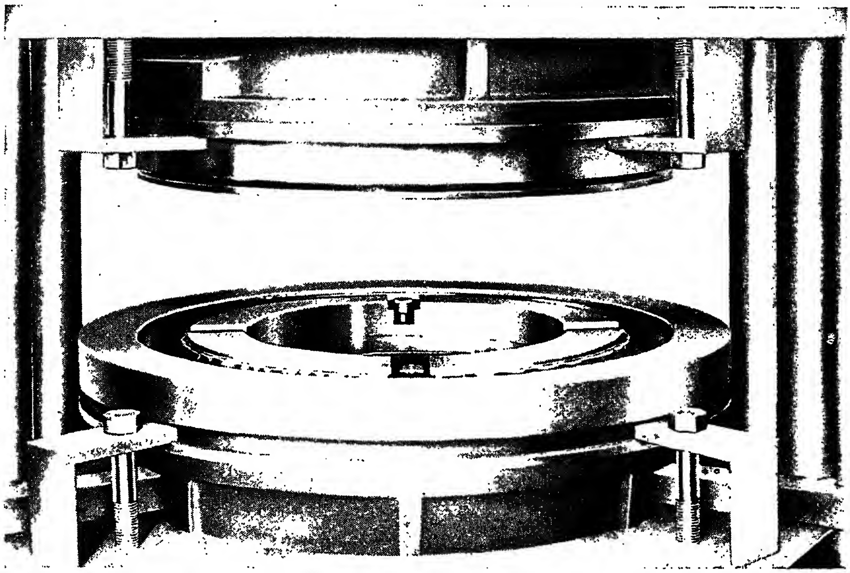

FIG. 32.—Single-cavity, built-up, positive mold for automobile steering wheel. A core-covering problem in which the core is a metal rim (integral with the spider) which is to be covered with a layer of plastic. Same work might be done in injection mold—depending upon type of plastic used.

capacity of molding presses available. They may include many special operating features not possible in a hand mold, of which the most important is the automatic ejection of the molded work. The time consumed in the actual molding is largely dependent upon the type of plastic used and is practically independent of the style of mold. Thus it may be seen that the time cycle may be shortened only in the loading or nonworking portion of the time. In the case of quick-curing mate-

rials, this idle time may be a large proportion of the total cycle, and here, particularly, semiautomatic molds are a great aid to production. The relatively high cost compared with hand molds is more than offset by the increased volume of product.

While the charge for mounting such a mold in a press is appreciable, the wear and consequent maintenance costs are negligible. In addition the heating characteristics of such a mold are generally better than those of a hand mold.

Heating.

Direct Heating.—The application of the heating medium is of importance where molds require alternate heating and chilling. The best condition requires that the mold be of minimum mass and that the heat be applied as directly to the metal of the mold as possible. When the heating medium may be thus applied to the metal in which the mold cavity is cut, the result is a direct-heated mold. While direct heating is never applicable to hand molds, it may apply to some semiautomatic molds. Press mounting of molds is the first requisite, owing to the steam connections required. Secondly, it is almost a necessity that each half of the mold, regardless of the number of cavities it may carry, be a unit plate of metal. Under such favorable circumstances it is not only possible but advisable to provide ports in the metal of the mold for the direct circulation of steam or water.

Indirect Heating.—The greatest contrast to the foregoing is found in hand molds. These molds placed between the platens of a press are heated or chilled indirectly through contact with the platens. The objectionable feature of this style of heating is not so much inherent in the method as in the characteristics of hand-mold operation, which subjects the heat-transfer

surfaces of both mold and platens to abuse. The effect of the resulting unevenness of surfaces is little appreciated by molders in general but represents an obvious opportunity for improvement of hand-mold performance.

Semiautomatic molds are usually built up of separate dies and seldom offer an opportunity for direct heating.

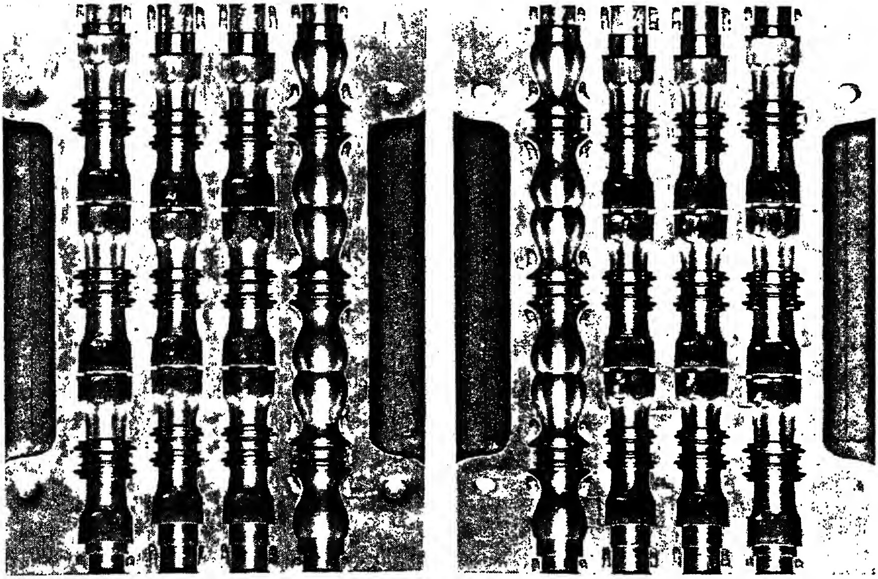

FIG. 33.—Unit-construction tube-blowing mold for brush handles. Mold requires press mounting for proper operation. Mold may easily be made direct-heated, with ports in the die plates, or steam and cooling water may circulate through the stock only.

The dies are backed by heater plates which become an integral part of the mold and supply heat indirectly to the mold cavities. Such molds are frequently referred to as being direct-heated, which is certainly not the case. However, since the heat-transfer surfaces remain in the original condition, the heating characteristics in such cases approach those of direct-heated molds. Where molds are to be kept continually heated, the practical difference is inconsequential, and any attempts to achieve

direct heating which increases the mold cost are not justified for such operation.

Incidental Features.—The feature of core covering is occasionally referred to in regard to style of molds. This again is a characteristic inherent in no particular type of mold, but to be incorporated, as required, in the design. Cores usually require retaining during the molding operation and are more satisfactorily accommodated in semiautomatic than in hand molds. Since there is little, if any, distinction between cores and inserts, except size in relation to the molded piece, the consideration of inserts in the following chapter may equally well be applied to cores.

The difference in style of construction which results in either unit, or built-up, molds has already been mentioned in connection with heating. The disadvantage of indirect heating with the latter type is a minor consideration compared with the advantages in the initial building of the mold and possibility of replacement of individual defective dies at any time.

CHAPTER V

GENERAL DESIGN DETAILS

With the type of mold determined chiefly by the shape of piece to be molded, and the size, method of operation, and heating determined by the foregoing considerations, the detailed design of the mold may be undertaken.

Since the basis of successful design lies in the individual mold cavities, it seems advisable to first consider only such details as relate to individual dies leaving details of the mold as a unit for the following chapter. Owing to the importance of multiple-cavity, semiautomatic molds, the present chapter is concerned chiefly with a basic unit of a built-up mold of this style, although many of the details apply equally well to molds of unit construction.

Materials.

Usual Requirements.—For the general molding process the usual requirements of metal for dies are that the dies may be given a fine polish and that this may be retained by hardening of at least the die surface. Until very recently, these requirements have been commonly met by the use of mild machinery steel, which is easily machined, may be pack-hardened to the desired depth, and takes a high polish when hardened. While such steel is by no means a standard, it may still be considered a normal choice for the usual run of work if the dies are to be produced by hobbing.

Special Considerations.—Within recent years, the production of dies by the special method of hobbing

has become of considerable importance. This method, which will be described in detail later, consists of forcing a hardened-steel hob into a soft-metal blank to produce the desired shape of cavity without machining. The hobbing method may be applied, on rare occasions, to high-carbon or tool steel and is moderately successful with alloy steels but is best suited to very low-carbon steels down to, and including, those grades known as special iron. Since hobbing insures precise duplication of dies and in addition is an economy when many dies are needed, modern multiple-cavity molds are largely of built-up construction and composed of hobbed dies. While such dies require a greater time and depth of pack hardening than the harder steels, they are nevertheless quite satisfactory.

So far as the plastic is concerned, it is found that the slight abrasion occurring in the mold is desirable in maintaining the initial polish of the dies. The wear on the dies from this source is imperceptible. Chemically, most plastics are inert toward the mold. However, an occasional plastic may be found containing traces of acid. In such a case the dies must be of stainless steel, or if they are of plain steel, they may be chromium-plated.

For ordinary use the expense of special steels is scarcely justified. Yet within recent years special alloy steels have been increasingly employed for dies. The most important consideration requiring the use of such steels is the matter of shrinkage of dies in the hardening process. This is of chief concern in the molding of precision parts of a mechanical nature, and for such dies the non-shrinking steels are most suitable.

The method of operation of the mold may have some bearing on the selection of material for dies. For example, dies of mild or soft steel may be used for work which is alternately heated and chilled. Ordinary high-carbon tool steel may prove quite unsatisfactory in the same

capacity, developing minute surface cracks which in time render the dies unsuitable for good work. On the other hand, when kept continually heated, such material is quite satisfactory.

Again, the type of work may influence the choice of mold material. This is apparent in the case of thermoplastics where the class of molding may not require great precision of product. As an example, pyroxylin is blown in cast-metal molds, in which the dies are finished by hand. The bulk of such work consists of blown toys which require great irregularity of shape of the die cavities. Cast-bronze molds are quite satisfactory for such work and, in being cast, represent a great economy over similar machined molds. Likewise, many rubber products, in the same general class as regards precision, are formed in cast-iron molds.

Mold Pressure.

Usual Case.—The first consideration in the design of the die is the pressure required to operate it. This depends upon the plastic to be molded and, if a thermoplastic, upon the temperature. The molding pressures given for various materials refer to the pressure required per square inch of projected die area. In a flash-type die, during final closure, the molding material between the cut-off surfaces, requires a pressure of equal intensity. Similarly, in a positive mold the material on the land must be considered in the same way. Thus the projected die area must be increased by the area of the cut-off (or land, as the case may be) in determining the operating pressure. From this, the total pressure required to operate the anticipated mold may be calculated or, conversely, the number of cavities which may be operated in a press of given tonnage.

Special Cases.—The molding pressure calculated above may on occasion be modified to suit special conditions.

Thus, as was mentioned in connection with positive molds, it is entirely possible that with dies of great depth the pressure may be so dissipated that the piece is incompletely formed at the bottom. A simple corrective for this, within limits, is to increase the total molding pressure by 5 to 10 per cent for each inch of depth of the mold. While this may be done even in the case of tableted compounds, the commonest cases are those of molding from loose material and apply particularly to positive molds.

In addition to the above, an allowance of 5 per cent is generally made for major sliding parts, such as the plunger of a positive mold. While in theory, at least, this should not be necessary, it is found that molding material does get between the plunger and bore of the mold, especially when the latter is worn.

Flash Surface, or Land.

Purpose.—The proper width of flash surface *B*, Fig. 34 (or land, in case of a positive mold) is important. In theory, this might be reduced to zero, but practically this cannot be done. In flash dies the resulting knife edges would soon be upset, while in positive molds the dies would produce pieces of varying height. In the other extreme, too much surface here will require excessive pressure to close the mold, and the resulting fin may be thick, causing trouble to remove.

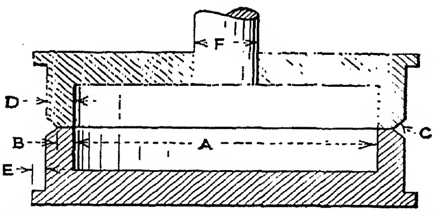

Fig. 34.—Individual flash-type dies with ejector pin.

Usual Allowance.—Experience shows that the fin formed in molding thermosetting plastics becomes increasingly difficult and expensive to remove beyond a thickness of 0.004 in. To this end, a width of 3/64 in. is

ordinarily used for B, for such work. While this may be applied equally well in the case of other materials, early trade practice has established a greater cut-off surface for the earlier plastics.

Special Cases.—It is apparent that a fixed width of cut-off results in varying proportions of flash surface to die area, the proportion decreasing with larger dies. The practical result of this is, that a point is reached, beyond which the unloaded dies cannot withstand accidental closure under full molding pressure, without deformation. This point is reached with a die area of about 1 sq. in. in the case of thermosetting plastics molding at 2000 lb. per square inch. Larger dies are occasionally designed to meet this possibility by use of a wider cut-off. Bearing pressures of 10,000 to 12,000 lb. per square inch on the cut-off surface may be allowed for such design in using mild-steel dies. The factor of safety is sufficiently high to prevent deformation under repeated closure. A higher bearing value may be used when there is assurance that such stress will not be repeated.

As an alternative to the corrected area above, the flash surface is occasionally held to a width of $3/64$ in., while additional bearing surface is provided in the form of landing strips or blocks placed between dies throughout the mold. Such blocks remain inoperative as long as molding material is being flashed from the dies, but lacking this the total pressure is distributed over the flash surface and landing blocks.

Usual Design.—Actually, while both of the above-mentioned safety measures are sometimes employed, the assumption is generally made that the mold will not be operated improperly. The second expedient is used on rare occasions to permit the operation of a large mold at partial loading and capacity. Such occasions are very infrequent. Relative to increasing the area of the

flash surface itself, it may be said that a wide flash surface, even with a reasonable increase of total mold pressure, will not produce the thin fin desired.

Excess material in flash molds is provided for by chamfering the surface beyond the cut-off area, as at *C*, Fig. 34. The angle commonly used for this is 45 deg. on each die. The chamfer serves a double purpose: first, adequate space is provided for the overflow, and second, the abrupt change in direction of the surface disengages the flash. Thus the simple illustration (Fig. 15), using merely a flat plate for the upper die, is not a desirable design as shown, and it may be expected that the overflow would be an annoyance in having to be removed from the upper die each time. Further to reduce mold cleaning, even where dies properly have the same width of cut-off, the chamfered surface requires a polish equal to that of the flash surface and the die itself. Dies so polished may generally be readily freed of flash by means of an air blast.

Wall Thickness.

When individual dies are used to form a multiple-cavity mold, the thickness of metal in the wall of the die may be of importance. Three cases in particular make a minimum thickness desirable: molds which are alternately heated and chilled; hand molds, where weight is important; and large molds, in which a maximum number of dies per unit of mold area is desirable. This thickness *D*, Fig. 34, is ordinarily made a minimum of $\frac{3}{16}$ in. apart from special considerations. In dies of considerable depth, this thickness may be kept at one-eighth to one-tenth the height of the wall. For the common case of dies circular in plan, the lesser thickness applies, while the thicker wall may be required if the die has plane vertical faces. Cylinder formulas cannot be applied, even for simple dies of circular plan, since the resulting

thin shells are not so easily manufactured as the heavier dies determined empirically above.

Draft.

Dies are ordinarily designed with a slight side-wall draft. While it is possible to produce moldings without draft, especially when the die cavities are relatively shallow—and such work is fairly common—it is desirable to have a slight draft of perhaps 1 to 3 deg. to facilitate hobbing if the dies are to be produced by this method.

Retaining.

If dies are circular in plan or lend themselves to being made conveniently from circular-bar stock, a most convenient way of fixing them in the mold is to insert them in a retainer plate, which holds them in contact with the heater plate. If this method of retaining is used, sufficient rough stock should be allowed, to leave a shoulder 1/16 to 3/32 in. wide, extending around the outer periphery of the die as at *E*, Fig. 34. Dies not circular in plan may be retained in much the same way, although in this case the shoulder is not continuous but is left on two opposite faces.

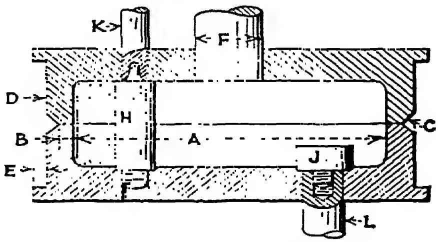

FIG. 35. — Individual dies showing inserts in place.

Ejector Pins.

The commonest method of ejection is by means of a single pin located in each upper die, as *F* shown in Fig. 34. Pins so located permit the removal of the work by means of a tray which receives all pieces at one time from the upper dies. Such pins are commonly made of tool steel, hardened and ground. The face in contact with the

work requires polishing and after each ejection must be returned to its initial position, flush with the adjacent mold surface. In order to provide a positive stop for the pin on its return stroke, a headed type of pin was at one time used, seating in the die. Such pins are not to be recommended, owing to the tendency of molding material to build up under the head, preventing proper seating.

Type of Pin.—The straight pin shown is operated in conjunction with the others in the mold by means of a bar or frame. The positive stop provided for a pin of this type is obtained externally to the die, in the operating mechanism. For large moldings, and particularly where dies are irregular in plan, several pins may be required for each die. The ejection force available depends upon the particular press used but is commonly 10 per cent of the net capacity of the press.

Top Ejection.—Dies should be designed to eject from the top whenever the cavities are numerous and the pieces small. Where this cannot be done, the ejector pins may be designed to lift the work high enough in the lower dies to permit the use of a comb. In using such a device the separate pieces may be removed at one time. In case of large pieces, hand removal from the mold may be advisable, in which case ejector pins may preferably be located in the lower dies.

Inserts.

Mention has already been made of cores and inserts, and of the general lowering of production occasioned by their use. Nevertheless, such parts may be essential to the product and must be provided for in the design of the dies. Two requirements must generally be met: positioning of the insert in the empty die, and retaining in this position during molding. Inserts may be broadly divided into two groups and may be handled in two general ways.

Simple Type.—The first type of insert extends through the molded piece as H, Fig. 35, and is the simpler to accommodate. Where such inserts are to be electrical conductors, binding posts may project beyond the face of the molding. Such projections may be used as pilots for locating the insert in the die, which is drilled to receive them. If the insert carries an axial hole rather than a projection, it may be positioned by means of a pin in the die, although this is not quite so desirable as the first.

Where neither feature is inherent in the insert as a matter of usefulness in the finished article, either may be deliberately provided to permit proper setting in the mold. While an auxiliary pilot of this sort requires subsequent removal, this may be less objectionable than using a drilled insert mounted on a pin. In either case, the insert positioned in the mold must be prevented from lifting or upsetting during closure of the mold. This may be accomplished by means of a dummy rod K, which passes through the upper die and presses on the insert before and during closure of the mold. Depending upon the stability of the insert, this rod may engage a pilot or hole at the upper end of the insert, or it may be plain. Such rods are best operated independently of the stroke of the press, and when so operated can usually be designed to act as ejector pins, when favorably located.

Second Type.—The second type of insert J is more troublesome to provide for, since in this case it must be positioned and held by a single device. For such inserts threaded projections may be provided which may engage a threaded hole in the end of a dummy rod L, which in this case is also a positioning rod. While the insert may initially be screwed into this rod, the rod itself must be free to turn so that it may release the finished work. Such rods, of course, cannot be used as

ejectors, and in general, the mold operation in such a case is very slow.

Location.—When inserts are to be molded in, it is essential for convenience that such inserts be placed in the lower die if the mold is to operate in the ordinary molding press. Tilting-head presses which were designed to facilitate the setting of inserts in top dies permit arbitrary location of inserts with equal convenience.

Shrinkage.

In the design of dies for extremely precise molding, the matter of shrinkage becomes an important consideration. In general, this shrinkage is of a twofold character, being made up of an initial material shrinkage, and a die shrinkage.

Material Shrinkage.—In regard to the material shrinkage, this varies not only with different plastics but also with various compounds of the same resin having different fillers or even different proportions of the same filler. The value of this shrinkage allowance must be known for the particular plastic under consideration. The shrinkage which initially reduces the size of the molded work after ejection is ordinarily not present after the work has once cooled to normal temperature but it apparently bears no relation to the linear coefficient of expansion of the finished work when thermosetting plastics are considered. In the case of thermoplastics, shrinkage may continue in diminishing amount during the entire life of the piece, thus making such materials unsuitable for precision parts. While in this case the effect of shrinkage may be to some extent offset by use of slightly larger dies, thermoplastics are so seldom thus applied that practically no importance attaches to such work. With thermosetting materials, for which the shrinkage may be quite definitely determined, a nominal increase in size of the dies is generally satisfactory. This

may be a linear allowance of perhaps 0.006 to 0.008 in. per inch for some of the commoner materials, based upon the work being ejected while still hot. If owing to other considerations the work is to be chilled under pressure, the shrinkage allowance will be much less and in the neighborhood of 25 to 30 per cent of that required for continually heated molds.

Die Shrinkage.—For precise work, the matter of die shrinkage is as important as the material shrinkage. Such die shrinkage is caused by the heat treatment required to harden the dies previous to their use and while usually smaller than the material shrinkage, is apt to be much more of a variable between different die materials. In the usual case, a grinding allowance is provided to allow for finishing to precise dimensions. This allowance takes care of both shrinkage and distortion incidental to hardening. When the shrinkage factor is unknown in any case or cannot be properly applied owing to intricate shape of die which does not permit subsequent finish grinding, special nonshrinking steels should be used.

Finishing and Hardening.

Since die shrinkage requires the hardening operation to be related to the design of dies, it may be well to consider this final preparation of dies in more detail.

Polishing.—After all machine work is completed, and previous to hardening, the dies are polished. This operation is, in the main, hand work and may be carried out to any degree of perfection consistent with the appearance or use of the molded work. In the earlier years of the molding industry it was common practice to produce practically all work with a very high finish. Since hand polishing of dies is a slow operation, it is not advisable to use a high finish indiscriminately on all work, especially on mechanical parts, where appearance

may be a very small consideration. Fortunately, highly polished surfaces have been losing favor generally as a standard finish. At the present time a dull gloss, called a matte finish, is usually preferred, and offers some economy in die finishing. Polishing may be a minimum for dies intended to produce relatively few pieces but may not be entirely dispensed with. The practical considerations are such that a very poorly polished die requires continual attention on the part of the operator. In the extreme, the economies of rough polishing may be many times offset by the cleaning required during operation.

Hardening.—Hardening of dies is essential to insure the polish against abrasion and to provide against crushing in case the unloaded mold may be accidentally closed under pressure. In a hardened die the very slight abrasive action of most plastics is sufficient to maintain the original polish of the die surfaces without causing appreciable wear. Unless scratched through careless cleaning, a repolishing of dies is seldom, if ever, required. The hardening operation may be varied to suit the particular steel of the dies but should not be carried to the point of extreme brittleness in the metal. The usual treatment with machinery steels of mild and soft grades, is to pack-harden the dies to a depth of $\frac{1}{64}$ to $\frac{3}{64}$ in., leaving a soft resilient core of metal. Bone dust, leather findings, or any other of the common carbonizing agents may be used for the operation. A light oxidation formed on the dies during hardening may be removed by a very slight polishing, before putting the dies into service. If the dies are to be used in making up a multiple-cavity mold, they may be finished externally by grinding to uniform size after hardening, for placing in a retainer plate.

CHAPTER VI

SPECIAL DETAILS

Semiautomatic Molds.

Semiautomatic molds are produced in two styles. In the first, the mold consists essentially of two mating die plates, in which the individual cavities have been machined. The second style of mold is composed of individual dies mounted to act as a unit.

Unit Construction.

Owing to the relative simplicity of the first style of mold, little need be said in detail, since much of the material pertaining to the more important built-up molds may be equally well applied to this simpler style. Such molds are essentially produced by machining, or by casting the die plates, the cast molds being applied in special fields only. While for molds having relatively few cavities machining methods may be advisable, the production of dies by hobbing becomes increasingly desirable with larger molds. Hobbing is seldom applicable to such unit-construction molds, and partly as a matter of manufacturing economy molds having many cavities are infrequently of this style.

Features.—Unit-construction molds operate perhaps to best advantage with plastics requiring chilling. Being press-mounted, such molds may be easily made direct-heated, with heater ports in the die plates. At the same time automatic ejection, and special operating features may be incorporated in the design as well as in built-up molds. A feature, perhaps of consequence even in

press-mounted molds, may be the bulk of the mold, which in molds of unit construction is less than in the other style. While the weight of such simple molds is generally less than that of the built-up style, this is influenced by the particular product being molded and is not invariably the case.

Built-up Molds.

The built-up mold is by far the more important, as especially in large sizes the dies may be produced by the hobbing process at much less cost than by the machining method otherwise required. In addition to this comes the accuracy of duplication inherent in this process of die making and the possibility of replacement of single dies in a built-up mold.

Size.—The first consideration in the design of the mold is the design of the individual die. From this is determined the space required per die and the molding pressure per die. Production considerations fix the number of dies required for the desired output. In the ideal case a press of sufficient tonnage should be available to handle a mold having the desired number of dies. Practically this seldom occurs, as in large production work the number of dies may be distributed between several molds, each of maximum size for the available press equipment. The problem, then, is usually one of designing the mold to suit a particular type and size of press. In this case, the pressure requirements per die being known, the tonnage of the press will determine the number of dies which may be operated. It will generally be found that the space requirements may subsequently be satisfied, since the total platen area may be 300 to 500 per cent of the projected working area of the dies.

Heater Plate.—The individual dies are mounted on a heater plate, which is usually of rolled steel. The steel

plate is relatively thinner than a corresponding cast-iron plate, and in having drilled steam ports it offers a more uniform channel for flow of steam or water. While more steam is required to bring the iron plate initially to the molding temperature, the rate of heating is little different, since the heavier iron plate may have proportionately larger ports. The face size of the plate in either case is dependent upon the press and on the method of mounting of the mold. If the face size of the heater plate is assumed to be the same as the press platens, it will be found necessary to make at least one, and usually two, deductions to determine the actual working space available for dies.

In the first place, the mold must be fixed to the press platens. While the most obvious way of accomplishing this is to pass heavy machine screws through otherwise unused portions of the mold, into the platens, this is seldom applicable to built-up molds. As a mounting for an individual mold this may be satisfactory, but as a system where interchangeability of molds is considered, this method is not desirable. However, in its relation to the size of the mold it is apparent that such a method of mounting allows the mold to be of the same size and shape as the press platens.

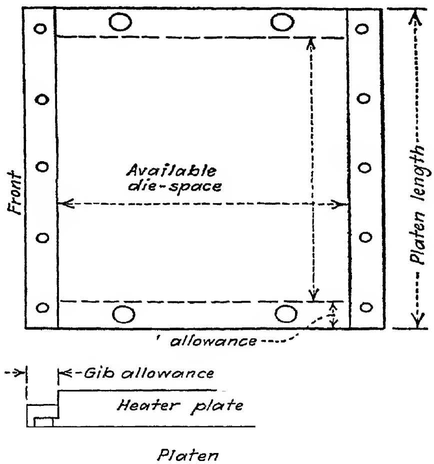

FIG. 36.—Relation of die space to platen area.

A commoner, and more desirable, method of mounting is shown in Fig. 36. It consists of holding down the mold by means of gib strips running along the front and

rear edges of the mold. If the platen is slotted, the gibs may be held down by T-bolts; otherwise cap screws may be used. In either case, it will be found necessary to reduce the dimension of the mold from front to back by approximately 3 in. to allow for the gibs, in the ordinary mold mounted in a press of 75 to 150 tons. A slightly smaller allowance may be made for smaller molds, perhaps 2½ in. The mold is ordinarily not held down along the right and left edges, and may thus be of the same length as the platens. The working space in this direction, however, must be reduced to allow for dowel pins. This amounts to 1½ in. at each end of the mold, in most cases, but will vary with the diameter of the dowel pins.

The working area of the heater plate determined, the dies may be spaced upon it. As previously mentioned, in a built-up mold the dies are usually of necessity placed in parallel rows. This spacing will locate the holes required in the heater plate, through which the ejector pins must pass, and this in turn determines the allowable location of the heating ports in the heater plate. The thickness of the heater plate, especially if mounted directly upon the press platens, may be a minimum consistent with the internal steam pressure, diameter of port, and the stresses due to handling in manufacture. A common thickness is 1½ in., which is sufficient if properly mounted. If for any reason part of the mold is left unsupported, excessive deflection may occur. This is quite possible in connection with mounting on bolsters instead of directly on platens. It is customary to place parallels under the otherwise unsupported portion of the mold, rather than to increase the thickness of the heater plate.

The arrangement of heating ports is frequently the same as in common cast-iron steam plates, with one inlet and one outlet at the back of each plate. A better

arrangement consists of two inlets at the back, near the ends, with a central outlet between them, as shown in Fig. 37. This may be especially recommended for alternate heating and chilling, as giving quicker and more uniform action. The ports are usually drilled ⅝ in., to accommodate the ½-in. steam piping generally used, but this is by no means standard and should be increased whenever possible, even though the inlet-pipe size may remain the

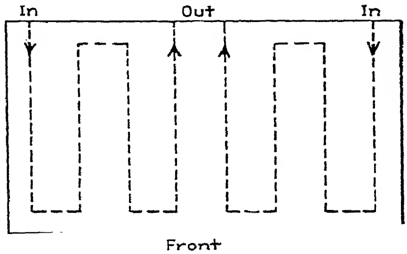

Fig. 37.—Common arrangement of ports in heater plate.

Retaining.—To hold the separate dies in their proper places on the heater plate, some sort of retaining device is required. This device must provide against lifting of the dies, lateral displacement, and, in some cases, rotation.

Since many dies are circular in plan, a convenient way of retaining them is by means of a plate in which they may be inserted from the back and which may be screwed to the heater plate, as shown in Fig. 38. To prevent the dies from slipping through the retainer plate, they are shouldered on the periphery, at the bottom, as previously mentioned. The retainer plate thus provides against lifting and lateral displacement. To prevent rotation, parallel flats may be cut by partially removing the retaining shoulder on opposite sides of the dies. A strip of proper size may be driven between the retaining and heater plates, aligning these flats on successive rows of dies. Needless to say, both retainer plates should be bored simultaneously to insure proper alignment of dies. This method of retaining is probably the simplest from the manufacturing standpoint, but may occasionally be found objectionable as a matter of

maintenance. Thus the removal of a single die requires the dismantling of the entire mold. To avoid this, the dies may be retained individually or in groups, by making the original retainer plate sectional. For dies of rectangular, but regular, plan, the retainer plate is replaced by gib strips bearing on shoulders on two sides of the dies. For dies of rectangular plan carrying an irregular

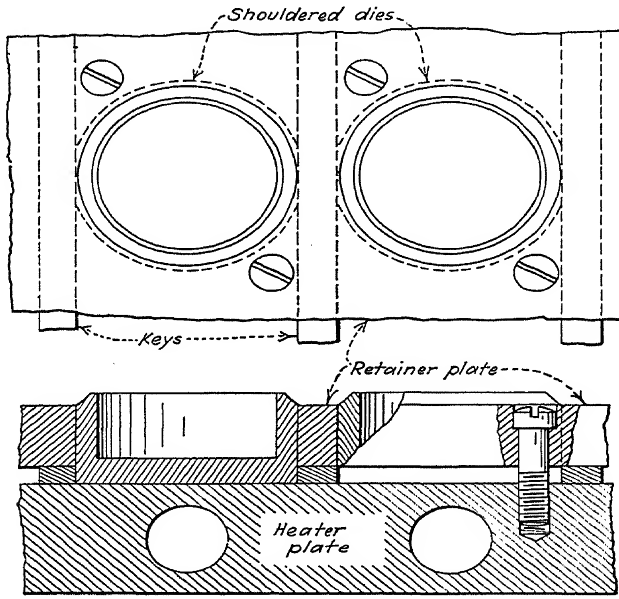

FIG. 38.—Dies held in place by a retainer plate.

cavity, an excess of material and space may offer the opportunity to fasten the dies directly to the heater plate by means of machine screws passing through the unused portions of the die material. Hence the absence of retainer plates on molds of this sort.

Dowels.—Despite the fact that semiautomatic molds are press-mounted, dowels are required for the exact alignment of the mold parts. In this connection it may be observed that a slight lateral motion of the movable

press platen does not denote poor press construction or adjustment. A lateral freedom of $\frac{1}{32}$ in. is quite advantageous in the operation of the mold, as the mold parts may be guided by the dowels without danger of lateral constraint by a rigidly guided platen.

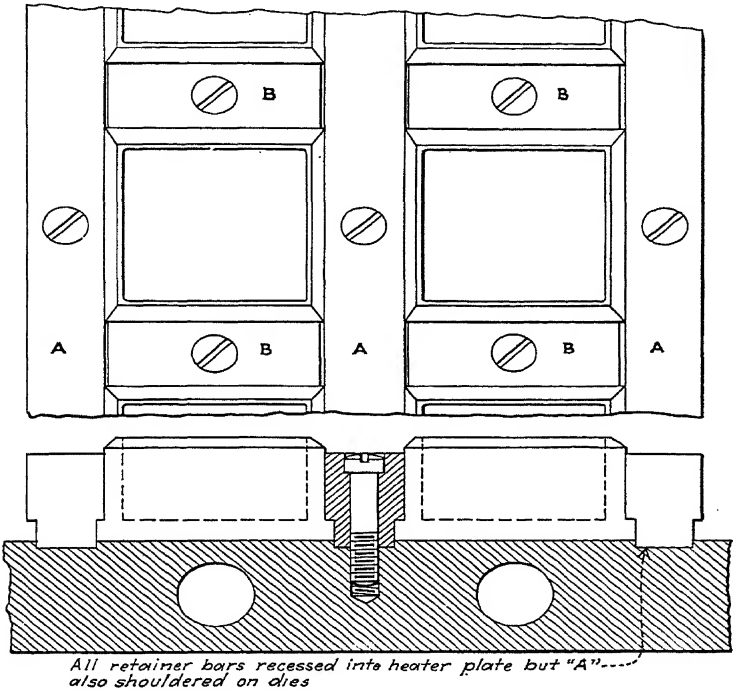

FIG. 39.—Alternative method of retaining dies—removable in rows.

Four pins of equal size are generally used, placed near the corners of the mold. Considering mold designs for 50-, 100-, 150-, and 200-ton presses, the pin diameters may be $\frac{3}{4}$, $\frac{7}{8}$, 1, and $1\frac{1}{8}$ in., respectively, or where fewer pins may be used, the same total sectional area of pins may be maintained. The style of pin and bushing shown in Fig. 41 may be recommended, as this allows a single and simultaneous boring of both plates to

accommodate both pin and bushing. The bearing of the pin B should be at least three-fourths of the diameter A and preferably equal to it. Both pin and bushing are shouldered and pressed lightly into place. The receiving edge of the bushing should be well rounded, while the nose of the pin may be any arbitrary curve, frequently

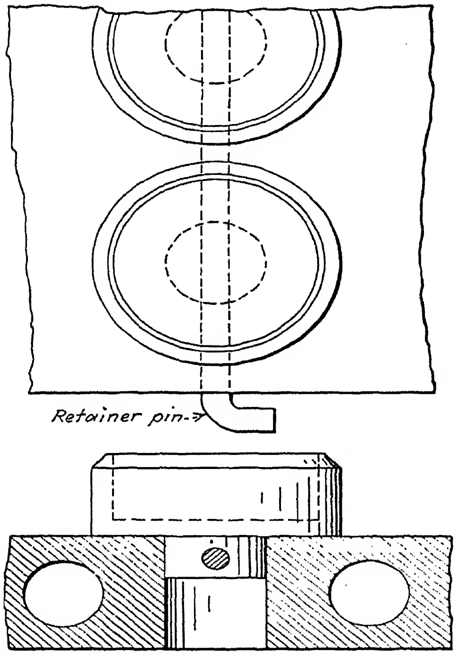

Fig. 40.—Alternative method of retaining dies—removable in rows. Usually easier applied to upper dies.

spherical. The parts made of mild steel may be lightly pack-hardened and ground to a sliding fit.

Ejectors.—While the ejector pin as a unit has been considered under the design of individual dies, the group operation of such pins may require further consideration in regard to the operating mechanism. In the simplest operation of pins, as in the old-style inverted-ram presses, the pins strike a positive stop near the end of the opening

press stroke, while the ram and attached half mold continue to the end of the stroke. This projects the pins in the dies, ejecting the work with the power of the pull-back ram which is used to return the movable press platen to its upper position. If the pins are located in the upper dies, they may strike a fixed stop attached to the inverted cylinder. Pins located in the lower dies may be raised for ejection by transverse ejector bars, upon which they rest and which are elevated by rods taking their motion from the movable platen above.

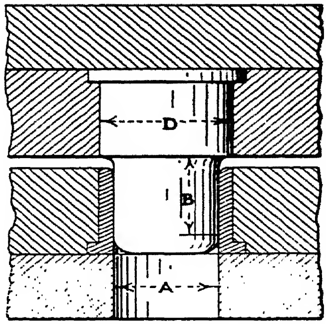

FIG. 41.—Simultaneous boring of both retainer plates insures perfect alignment of dowels.

Since each transverse row of pins would otherwise require a pair of vertical rods to operate the ejector bar, it is customary to combine the several separate bars into a unit called an ejector frame which may be operated as a whole by two or four rods from above (see Fig. 42). Similarly, for top ejection the rows of pins are actuated by a frame composed of separate bars, as the frame can be more easily operated than the individual pins. In either case, however, while this method of ejection may project the pins with sufficient force for ejection, no provision is made for reseating the pins in the dies.

As a means of reseating ejector pins a so-called stripper cylinder has been added to some of the older presses. Thus a small hydraulic cylinder is opposed to the return cylinder and kept on line pressure at all times. As the main ram is operated in opposition to the return cylinder, the stripper acts on the ejector frame to return the pins. The design of the mold in such a case may include much more than the actual mold. Thus the half of the mold containing the ejector pins must be mounted on a

grid separating it from the platen so as to provide space for operating the ejector frame. Since the supporting ribs of the grid must be spaced between successive rows of pins, a grid suitable to one mold may not be usable for another but must be considered more or less a part of a particular mold. Likewise, the ejector frame, to which the ejector pins must be fixed, is generally suitable to

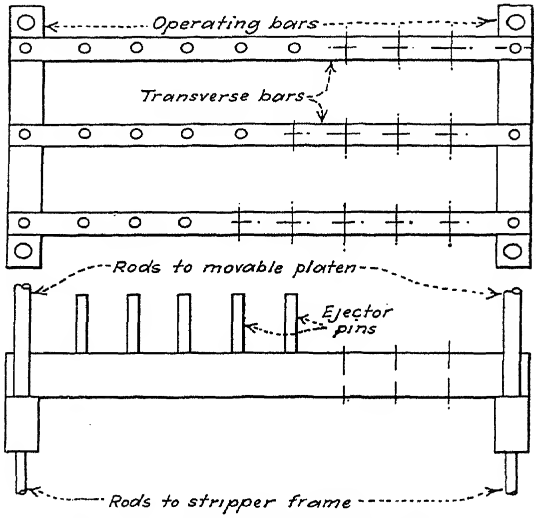

FIG. 42.—Ejector frame assembly.

the particular mold only and must be designed for each case.

While the operation of such a mold may be entirely satisfactory, the cost of the special accessories and the set-up charges are frequently excessive, running occasionally into several hundred dollars. To avoid this repeated expense, newer molding units incorporate some of the mold features in the press itself. Most important of these, and directly suggested by the stripper cylinder, are differential ejector cylinders which act positively in either direction and are independent of the stroke of the press ram.

These cylinders actuate master ejector bars, to which the transverse bars may be attached with any desired spacing. The ejector considerations in this case end with the design of the transverse bars, to which the pins are attached. The special grid previously required is replaced by adjustable bolsters and parallels which may be arranged to suit each mold. Incidentally, it may be observed that it is entirely possible to combine

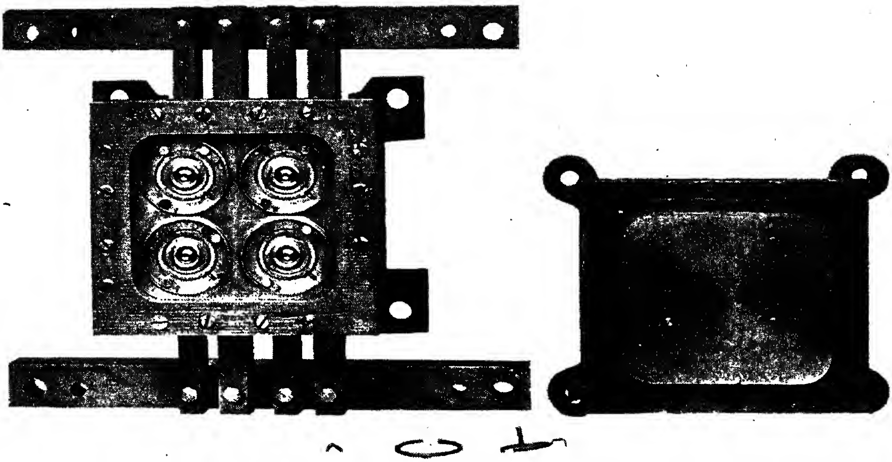

FIG. 43.—Four-impression subcavity mold showing ejector frame, designed for press having separate pull-back and stripper cylinders. Metal inserts for the molded work are shown below mold.

the force of the return cylinder with that of the ejector cylinders on a press of this type. For the ejection of very deep work requiring heavy pressure this may be found convenient. Since the return and ejector cylinders nominally are each rated at 10 per cent of the net press tonnage, the resulting 20 per cent provides for extreme conditions and requires special consideration in the size of ejector pins and bars.

Heating.—The arrangement of ports in the heater plate previously discussed may be recommended for all

general use. This consists of two end inlets and one central outlet at the back of each heater plate, in conjunction with parallel drilled ports. While for alternate heating and chilling, this method may not provide absolute uniformity, it does so sufficiently for all practical purposes. The involved port arrangements sometimes suggested are seldom applicable to a plate drilled from the solid and are much more expensive.

A method offering better efficiency than the one recommended employs direct heating in order to bring

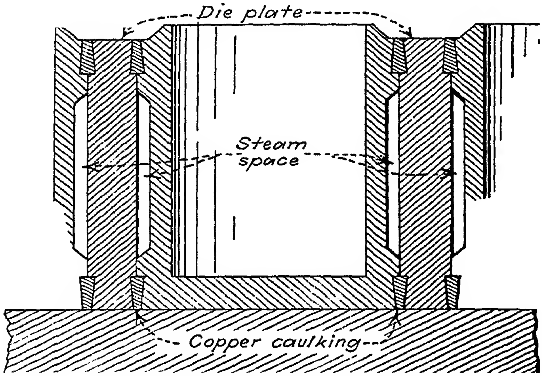

FIG. 44.—Direct heating of multiple-cavity molds.

the steam in direct contact with the metal of the dies. For a unit-construction mold, of course, this is relatively simple, since the heating ports may be drilled directly in the die plates. Unfortunately, such opportunities are rare. To accomplish the same in a built-up mold, the usual heater plate may be replaced with a thin solid plate. This in conjunction with a special retainer plate carrying the dies, as shown in Fig. 44, forms the lower half of the mold. Soft copper may be used in caulking the dies in the retaining plate. The annular space provided for the caulking is preferably a trifle undercut. Needless to say, the cost of such a mold is prohibitive for ordinary use, and such construction is

reserved for single-impression molds or for molds having relatively few dies. If the mold is to be kept continually heated, such a heating method is not to be considered.

Where molds are alternately heated and chilled, it is frequently found that the upper and lower dies do not heat at a uniform rate. This is most often caused by an improper distribution of metal in the two parts of the mold and should be taken care of in the design. The usual corrective consists of first designing the larger half of the mold for minimum weight consistent with

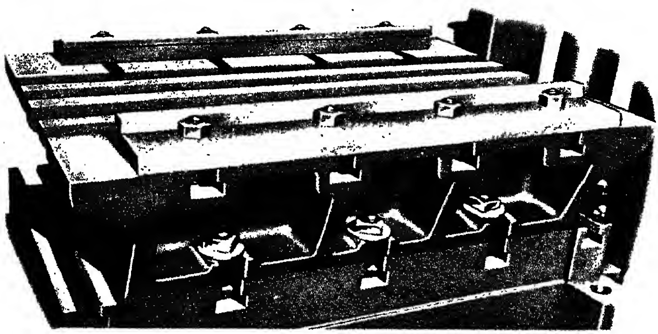

FIG. 45.—Bolsters, parallels, and gibs for mounting mold. Note master ejector bars at ends of platen.

strength requirements, after which excess metal is allowed in the other half mold, to equalize the mass in each. Since the radiation loss is naturally greater from the bottom than from the top dies, even this precaution will not guarantee absolute uniformity in the heating rates of the two parts but usually reduces the difference to a negligible amount. This detail of design is sometimes observed even in the case of molds continuously heated but, of course, is of less importance for such operation.

A further consideration in regard to heating is the expansion of the mold as a whole. Trouble is sometimes

experienced in improper alignment of dies under working conditions, although the mold may be satisfactory at normal temperature. This may be caused by improper choice of materials for whatever retaining devices are used for lateral positioning of the dies. In the usual case of one-piece retainer plates, it is important that both upper and lower plates have the same coefficient of expansion. Since these retainer plates are fixed to the heater plates, it is advisable that these be made of a similar metal, and these parts are generally made of rolled steel. A mold built up of steel and cast-iron parts gives trouble unless carefully designed for expansion. A mold of this sort may be satisfactory if the dies are individually retained, provided that the heater plates are of the same material.

Mounting.—The use of gib strips has been mentioned in connection with mounting the mold in the press. This method of mounting may be recommended as the most flexible system devised for the purpose and is particularly effective in reducing the set-up cost of large molds. Figure 46 illustrates such a mounting in connection with a press having adjustable bolsters. The section is taken through the press from front to back, and shows the lip left on the heater plate A, for holding down. The lip may be ¼ in. wide and ¼ in. high, and does not extend around the ends of the heater plate, being only on the front and rear faces. Through-bolts C are commonly used for holding the gib B. The bolster D may be moved to suit the width of the mold and is held to the platen E by means of T-bolts F. The transverse ejector bar G actuating the ejector pin H, is designed to operate between the heater plate A and platen E and ties into the master ejector bars running from front to back at each end of the platen. Where the span between bolsters is great, parallels such as J may be used to support the central portion of the mold.

Although it is seldom necessary, long machine screws K, may occasionally be used to hold down the central portion of the mold, one at either end being sufficient even for a full-width mold. The heater ports parallel to the section are not shown, L being one of the two cross ports connecting them at the ends.

Referring to K, such machine screws are sometimes the sole means of holding down a mold, especially in con-

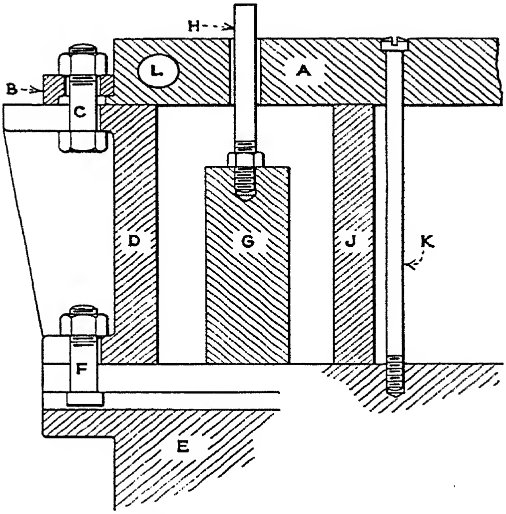

Fig. 46.—Bolster mounting of the mold.

nection with old presses in which a cast-iron grid is used for supporting the mold, rather than adjustable bolsters. This requires a great number of screws, of which many may be difficult to install. The proper tapping of the platens to accommodate the screws of the one mold offers no latitude in installing other molds, since the holding-down screws must be similarly spaced. The alternative of several sets of holes in the platens to accommodate several corresponding sizes of molds still lacks the flexibility of the method shown and adds an otherwise unnecessary consideration to the mold design.

Type Details.

Much of the foregoing text applies to molds in general and especially to multiple-cavity molds of flash and semipositive or closely allied designs. Since many mold types vary by a single detail, the special features in each case may be considered by themselves without repetition of the foregoing generalities.

Semipositive Molds.—The mounting of semipositive dies may be exactly the same as in flash-type molds, the only special feature of design being inherent in the individual die design. Thus a relatively short plunger is used for the upper dies, entering the lower dies $\frac{1}{32}$ to $\frac{1}{16}$ in., for which a corresponding allowance in height must be made. A refinement of the lower dies consists of rounding the receiving edge with a radius of $\frac{1}{64}$ in.

Since the item of chief importance in connection with this mold is the vertical fin of uniform thickness which may be produced, it is essential that the plunger be given the proper clearance on the sides. This may vary somewhat to suit different plastics, but for those of the thermosetting type the fin is limited to 0.003 in. thickness, while on occasion as little as 0.001 in. is allowed. Since in almost every instance, the flash surface is required to be at the top of the piece in designing such dies, the height of mold may be chiefly due to the lower dies. An excess of metal may be required in the upper half mold to give uniform heating characteristics.

Stripper-plate Molds.—In the stripper-plate mold, ejector pins are eliminated, the stripper plate itself removing the work from the top dies. The stripper plate is best operated by means of a differential ejector cylinder, although it may be made to function in a press having pull-back and stripper cylinders. The motion is taken from the ejector cylinder through a spider carrying vertical rods fixed to the stripper plate.

Occasionally four rods may be used, one at each corner of the plate, but with the long narrow molds preferred for large production this is quite likely to be unsatisfactory.

The chief cause of trouble with this type of mold lies in designing the stripper plate for strength rather than deflection. If it be regarded as a uniformly loaded beam, the deflection should be held to 0.002 to 0.004 in. For a plate supported only at the corners the thickness required for this deflection is excessive and more support is ordinarily furnished to permit use of a plate of reasonable thickness. While some press units are designed to care for this condition, others may require a special ejector spider allowing the stripper plate to be supported at the center of the front and rear edges as well as the corners. A second cause of binding may be avoided in using the same material for both stripper and retainer plates, for uniform expansion.

Subcavity Molds.—In subcavity mold design the communication maintained between the separate cavities during molding requires that the total molding pressure be based on the area of the single large cavity. In keeping the proportion of flash area to die area as small as possible it is frequently necessary to nest the impressions for compactness. In spite of this precaution the excess of molding pressure over that required for the cavities alone may be as much as 50 to 75 per cent. These molds are rarely built up of separate dies, and thus being unit-construction molds they are particularly well suited to direct heating. The depth of the lower die is determined from the compression ratio of the particular bulk material to be molded which in the case of the commonest wood-flour mixture is 2½ times the volume of the molded piece. Ejection from the lower dies is usually necessary, since the plunger is made with flat face whenever possible, to save cost.

The fore part of the plunger to a distance of $\frac{3}{8}$ in. back from the face is fitted to a clearance of no more than 0.001 in. at each side wall. The remainder of the plunger is relieved on the sides to a depth of $\frac{1}{32}$ to $\frac{1}{16}$ in. to prevent lodging of molding material, and consequent binding. An allowance of 5 per cent in tonnage may be made to offset the friction of the plunger. The necessity for polishing the sides of the die and plunger is apparent. If, owing to a high compression ratio of the molding material, the plunger is relatively long, it may be found advisable to make this as well as the lower die direct-heated. Ordinarily, the plunger may be mounted on a heater plate, and if drainage is important this may be the only possible means of heating.

Positive Molds.—In designing positive molds it is well to remember the exactness required in measuring the mold charge, for uniform results. This factor requires that more than ordinary care must be used in obtaining uniformity in individual dies if a multiple-cavity mold is designed. Occasionally small parts carrying inserts or cores may make a positive mold of this sort advisable, but fortunately such cases are not frequent. A more common requirement is a positive mold having a single large cavity for which the preforming of the bulk material may be impractical.

The depth of the lower die, as in the case of the subcavity mold must be determined from the compression ratio of the particular plastic to be molded. One difference here is that materials having a bulky filler such as shredded material, or canvas scraps, may be used in this mold, while not so well suited to the subcavity mold. Since compression ratios in this case may be as high as 6 or 8 to 1, positive molds in general may require much deeper dies than other molds.

The bottom die may be direct-heated by ports drilled in the metal, but since the mold is deep it may be advis-

able to heat the side walls as well as the bottom. As it is usually impossible to provide ports for this in the metal of the die, an alternative method may be used for single-cavity molds. This consists of surrounding the die with a cast-steel shell, inside which steam may be circulated. Copper caulking may be used for the joints as previously mentioned in connection with similar heating of a multiple-cavity mold.

The upper die, or plunger, being relatively longer than that of the subcavity mold, may more often require direct heating. The plunger is less likely to be flat on the face than the subcavity plunger and hence may be used as a means of lifting the work for top ejection. However, since the advantages of top ejection are most apparent with many cavities, which is seldom the case here, little effort need be spent in accomplishing this if the opportunity is not obviously present.

Split Molds.—Split, or three-part, molds are best operated in an angle-molding press designed for the purpose. The ordinary method of mounting may be used, one half of the bottom die mounted on the fixed rear face of the vertical abutment, while the other half is fixed to the movable vertical face of the platen operated by the main horizontal cylinder. It may be remembered that these two parts mate, apparently like flash dies, with the difference that no molding material is expected to escape between them since they are locked together by the press. Thus the remaining land of the relieved faces may be of greater width than the cut-off surface of flash dies.

These two halves of the mold are doweled for proper alignment and, being generally of unit construction even though multiple-cavity, lend themselves readily to direct heating. In arranging for ejection from these lower dies it must be remembered that the ordinary angle-molding press is not equipped with independent

ejector cylinders. The pull-back cylinder is used for this purpose.

The two lower-half dies as a unit are designed to act as a single die with respect to the third part of the mold mounted on the face of the upper vertical ram platen and operated by the main vertical cylinder. This part is usually in the form of a plunger, which may guide itself to a proper seat in the lower dies. If not, it may be doweled to engage the fixed lower-half die but not the movable half, as improper operation of the press would otherwise injure the mold.

If the plunger reaches to the bottom of the mold, it may be provided with a tapered pilot to insure proper alignment in the mold. A long plunger, if of sufficient diameter, may be drilled for direct heating. In designing the plunger it may be found that the tonnage of the vertical cylinder is greatly in excess of that required. Allowance must be made for this in the width of land provided, to withstand crushing.

Split molds may be operated successfully in a semi-automatic press, especially when the core is relatively small. For such operation, the main parts of the mold are mounted on the press platens, leaving the plunger in a horizontal position. This may be operated by a hydraulic cylinder especially designed for the purpose, and attached to a fixed point of the press. Since the average press will withstand only a nominal lateral pressure on the main rods, a special operating cylinder attached to the press rods generally requires an opposed cylinder to balance the thrust. As the rods are generally the most convenient point for attachment such design is sometimes used. As may be seen, this leads to considerable equipment special to the one mold, and is recommended only as a means of accomplishing the special work, lacking the proper press.

Floating-chase Molds.—The similarity of the floating-chase and stripper-plate molds has been previously mentioned in regard to the initial trapping of the material. Yet this detail, which is largely incidental in the case of the stripper-plate mold, is fundamental for proper action of the floating-chase type. The importance of the unrestrained chase is not to be overlooked, as occasionally an improperly designed mold of this type defeats its very purpose in this detail.

The upper and lower dies are designed to telescope into the chase ring and to be brought to a positive stop by means of lands in the chase. The mold is to be loaded with the proper amount of material, making flash action unnecessary, this latter being practically impossible to design for in this type of mold. The height of the chase must be sufficient to contain the molding material, when the lower die has entered the chase by about ⅛ in. For this initial loading position the chase must be supported by some means. A small hydraulic cylinder or coil springs may be used for the purpose. In either case, the supporting force, although positive, should be no more than is actually required. Except for this insignificant support, the chase is free to move vertically relative to either die during the molding operation. If this action is lost through the chase bearing on either platen during the operation, the mold is little more effective than a simple positive or stripper-plate design.

As ordinarily constructed for a multiple-cavity mold, the chase consists of a thick steel plate, in which holes are bored for guiding the dies. So designed, the chase is generally drilled for direct heating, while the dies may be mounted on heater plates. The sliding surfaces of this mold require polishing, and the clearance of the dies in the chase should be no more than necessary for a sliding

fit. The width of land on the dies need be no more than that required to avoid crushing.

A floating-chase mold is sometimes used in the covering of a horizontal core, with plastic material. For such use the ordinary chase would be split horizontally, as shown in Fig. 47, and the core would be carried by this two-piece chase, with less chance of displacement than in the ordinary mold. Usually the floating-chase action is entirely lost, in that the upper-half chase advances

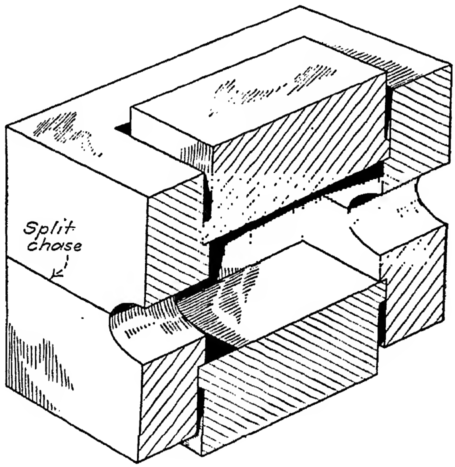

Fig. 47.—Possible application of floating-chase mold to accommodate the positioning of horizontal cores.

positively with the upper die. While for shallow dies this may not be unsatisfactory, it is not permissible for deep work. In this latter instance, if a two-piece chase is used, means must be provided for locking the parts together after setting the core, so that the parts may act as a single chase. A mechanical lock is more practical for this purpose than a hydraulic device, because of the freedom of movement required of the chase, which is impaired by a hydraulic connection.

Blowing Molds.—Blowing molds for pyroxylin sheet stock and for rubber are essentially hand molds. How-

ever, the blowing of pyroxylin tube stock requires press-mounted molds for proper operation of the blowing nozzles. The molds are generally of multiple-cavity, unit construction and lend themselves to direct heating.

The press need be little more than a locking device, such as a hand-operated screw press. The tapered nozzles used to introduce steam or cooling water inside the stock are mounted on two manifolds, one at either end of the tubes. Axial motion of the nozzles is necessary to crowd them into the exposed ends of the tubes to form a tight joint. This may be accomplished by operating the nozzle manifolds by means of a hand wheel and screw. The motion required is not more than one inch.

Since the blowing operation begins with the mold in a closed position, cut-off edges as such are not required. The mating faces of the dies are nevertheless relieved, to insure contact at the edges of the cavities. Dowels are used for alignment of dies. Depending upon the spacing of the tubes, new manifolds may be required for each mold. Owing to the economies of using sheet stock, the blowing of tubes may be considered special blowing work.

Injection Molds.—Injection molds as used for cellulose acetate and pyroxylin are essentially hand molds. In applying this type of mold within recent years to thermosetting plastics it has been found desirable to mount the molds in machines carrying the extrusion cylinder as an integral part. At the present time such molding is confined to relatively small parts but is particularly well suited to concentric covering of slender cores and to production of intricate shapes, especially those complicated by very thin wall sections.

In applying the injection method without the use of special press equipment, molds have been designed for use in semiautomatic presses. These molds, substan-

tially the same as those used in the general method, are mounted as usual, with the exception that the extrusion chamber is placed upon the mold. The chamber, while not integral with the mold, is considered a part of it, since a different one may be required for each mold. This chamber must be loaded with the proper amount of material for each mold charge, since any excess curing in the chamber cannot be extruded and must be removed.

Upon operating the press, the material which has been heated to plasticity in the extrusion chamber is injected through one or more nozzles. These nozzles engage a set of ports extending downward through the upper dies, into which the material is forced. In injecting thermosetting plastics it has been found advisable to use special mixtures containing more than the usual amount of resin to obtain good flowing qualities.

The extrusion pressure is not standardized, being a variable dependent upon the size of ports in the mold. Experimentally pressures as high as 30,000 lb. per square inch have been used in the extrusion chamber, while commercially pressures of 8000 lb. have proved satisfactory.

Since injection molding leaves a sprue of material on the finished work, this may prove troublesome and require a special finishing operation. To avoid clogging of the ports, they may be tapered from the nozzle to a larger section at the work. Upon ejection, the sprues, with the work, will be removed from the mold. Multiple-cavity molds of the foregoing description have been built on the assumption of better production than the general method. These hopes have not been realized, except in the very special cases for which injection is particularly suited.

At present it would appear that multiple-cavity injection molds may remain limited to a size which will permit only moderate production. For thermosetting

plastics especially, the injection method may be considered to augment, rather than to displace, the general method.

Hand Molds.

Hand molds represent a much simpler, but more limited, style of mold than those designed for press mounting. At the outset, automatic ejecting devices as well as direct heating are out of the question. The supporting of inserts is still feasible and occasionally becomes even more simple than in semiautomatic molds.

Construction.—Hand molds may be of either unit or built-up construction. Generally being used for job molding where mold sizes may be small, unit construction is more common than in press-mounted molds. However, the possibility of replacement of single dies in the built-up mold is as important here as in semiautomatic molds and occasionally leads to the use of an assembly of hobbed dies.

Weight.—In regard to the maximum weight allowable for hand molds, 50 lb. may be considered a practical limit for ordinary operation. Even this may be found excessive in the case of molds operating on a very short cycle. Molds of unit construction are less bulky than those built up, and thus easier handled. In regard to weight, the unit mold is generally lighter, since the separate dies of the built-up mold cannot be spaced as closely as in the simpler mold. In either case, however, some gain is made over the semiautomatic design in that the cavities may be placed in staggered rows for more compact arrangement. This cannot be accomplished in press-operated molds, owing to the interference of the ejector pins with the heater ports.

Dowels.—As in semiautomatic molds, the dies are made to mate properly by means of dowel pins in the main mold parts. Depending upon the size and shape

of the mold, two, three, or four pins may be used. These should be so designed or spaced that the upper half mold will not fit the lower, if turned end for end. Thus if the dowels are symmetrically spaced, they should be

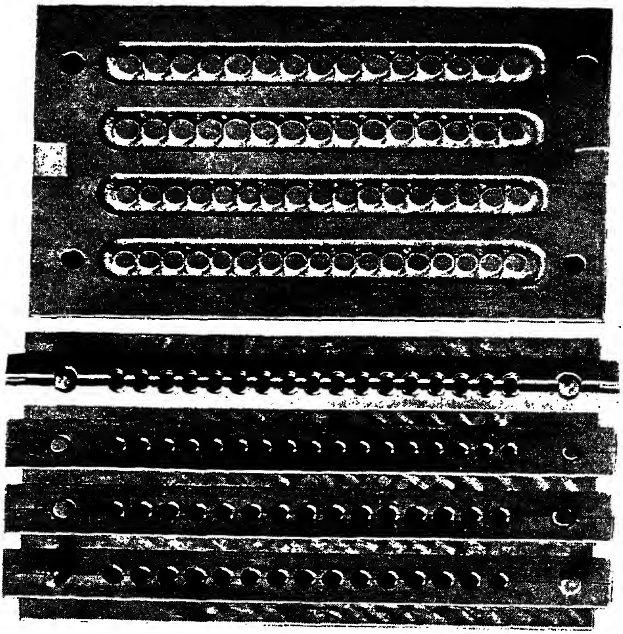

FIG. 48.—Hand mold producing undercut parts of spool shape. Molded with axis vertical, parts may be removed after lifting the split bars from lower die plate.

made in two sizes, or if it is desired to keep them of uniform size, they should be irregularly spaced. While desirable even in the case of press-operated molds, this is a particularly important feature in hand-mold design.

The pins are usually located in the upper half of the mold, to engage hardened-steel bushings in the lower

part. Pins and bushings may be finished by grinding, and both may be pressed into place.

In regard to size of dowels, it may be seen that there is little basis for exact computation. As a result, these may be found of various sizes in molds of equal size. However, the practice of using dowels as large as possible is commendable, especially for hand molds, in which case the mold parts may be improperly aligned before the mold pressure is applied. A satisfactory size of pin for a hand mold operating at a pressure of 75 tons is 7/8-in.

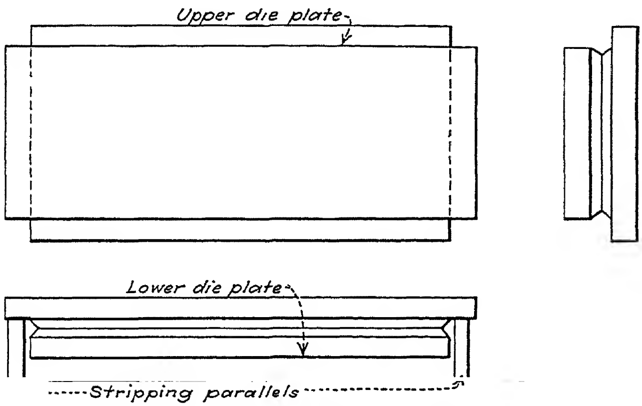

FIG. 49.—Stripping arrangement for hand molds.

diameter where four pins are used, or the equivalent sectional area in case of fewer pins. It is not advisable to use pins of less than 1/2-in. diameter, even on small molds, otherwise the total sectional pin area may be proportioned to the tonnage as given above.

Opening Molds.—To facilitate opening, the parts of a hand mold, as shown in Fig. 49, are not exactly the same in plan outline. Thus the upper part is allowed to overhang so that the mold may be supported on blocks at these points, while the lower part may be stripped downward. This is accomplished easily in a hand-operated arbor press by having projections at the ends

or sides of the lower-half mold which receive pressure simultaneously from a descending spider attached to the arbor-press ram.

Heating.—Since hand molds are indirectly heated, it is important that surfaces transmitting heat have a smooth finish. Although such surfaces are frequently given a tool finish, a ground face is more effective for rapid heat transfer. In the case of unit-construction molds, the two faces in contact with the press platens may be ground. For built-up molds, not only these corresponding surfaces, but the bottoms of individual dies as well as the plate upon which they are mounted should be carefully finished.

Steel dies for hand-mold use require the usual polishing and hardening. In the case of large unit-construction molds, especially when relatively shallow, a slight warping or buckling may result from the hardening operation, which may require a very light grinding of the flash surfaces and backs of the plates. The amount of material removed, while slight, may be sufficient to warrant previous allowance in the depth of the die cavities to the extent of 0.005 to 0.010 in.

Split Molds.—Three-part molds may be designed for hand operation. In principle, the lower portion of such a mold is made in two main parts which mate in a vertical plane. While the contact faces are relieved, leaving a land resembling the cut-off of a flash mold, the dies are in contact during the entire molding operation. Relieving of the surfaces is thus a matter of insuring proper contact between the vertical dies, and the width of land is arbitrary, generally ⅛ in.

The usual doweling is required to align these dies which are most conveniently held together during molding by means of a chase, as shown in Fig. 50. Two opposite inside faces of the chase may be tapered to make contact with corresponding tapered backs on the

vertical dies. Allowance may be made for grinding the bottom faces of the dies occasionally, as continual wear allows them to become loose in the chase. While not so of necessity, the third part of the mold is most often in the form of a plunger. In any case, this part, and the two lower dies considered as a unit, may be designed as a two-part mold.

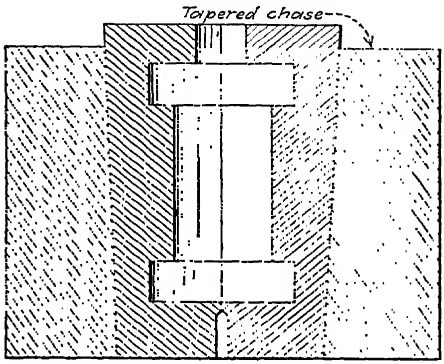

FIG. 50.—Split or three-part mold, for hand operation.

Injection and Blowing. Hand molds for injection and blowing are chiefly of cast bronze and therefore of unit construction. In the case of injection molds, while the mating faces are relieved to insure proper contact, the width of remaining land is arbitrarily 1/8 in. In the case of blowing molds, although the land is actually used to cut off excess stock, a greater width of surface is used than in steel molds, being from 1/16 to 3/32 in. wide. While the relatively soft plastic does not require this greater width, a low compressive strength of the mold metal may make it necessary.

Blowing molds are peculiar in requiring venting to permit the escape of air initially in the die cavities. This is done by drilling from the backs of the die plates, with a very fine drill which is allowed to barely break through the surface of the die cavity. All of the various depressions of each die cavity need to be vented to avoid minor air pockets.

The size and shape of port provided in the mold for the introduction of an injection nozzle are arbitrary, depending upon the size of cavity to be filled with material. A tapered nozzle carrying a 1/16- to 1/8-in.

hole is large enough for average work. The taper may be abrupt, since the nozzle is rigidly fixed to the extrusion machine and thus prevented from backing out of the port in the mold. In the case of blowing molds, a smaller port is provided for the blowing nozzle, which in this case may be no more than 1/8- to 3/16-in. outside diameter and carry a very small hole. Since this nozzle is portable, it is held in place merely by the friction of the plastic against it. To prevent backing out, the outside taper is very slight.

The various dies of a multiple-cavity blowing mold must allow communication through channels for compressed air. The mating channels are made approximately 3/32 in. wide and 1/16 in. deep in each die plate, depending upon the thickness of stock being blown. The foregoing applies especially to molds for blowing pyroxylin or similar material. In the case of blown rubber goods, the mold design is simplified by the fact that the goods may be blown by gas pressure. This eliminates the channels between dies and the inlet port previously mentioned.

CHAPTER VII

DIE HOBBING

The Hobbing Process.

The method of producing dies by hobbing originated many years ago, apparently among jewelers who used this so-called die pressing for making relatively simple, shallow molds for the pressing of precious metals.

Original Method.—Hobbing consists essentially of sinking a hardened-steel replica of the piece to be molded into a softer steel blank. The blank receiving the impression from the hob may be used as a die for molding. Since there is no measurable wear on the hob, successive dies may be made from it indefinitely producing exact duplicates essential in multiple-cavity mold construction. The process is distinct from forging, in two respects: the work is at normal temperature, and the hob is sunk slowly under continuous heavy pressure, with complete absence of impact.

Shallow dies may be satisfactorily produced in this way, but the demands for deeper dies usually required in plastic molding forced an improvement on the original process. Thus the flow of metal in the blank is accompanied by a certain amount of lateral displacement. This may be sufficient to limit the use of such dies to the production of goods where close tolerances are not essential.

Improved Method.—To produce accurate dies of desirable depth, a heavy chase ring is used to confine the blank laterally. This chase consists of a steel forging having a cylindrical hole vertically through the center and fitted

with a hardened-steel bushing. In using this, the blank in the form of a disk is made a sliding fit in the chase and placed in the hole so as to rest on the bottom platen of the press. The hob, also a sliding fit in the chase, extends above the ring. The base of the hob bears against the upper press platen, the face being in contact with the blank to be hobbed. In this way, the metal displaced in the blank is caused to flow up the sides of the hob, constrained against lateral flow by the chase. Dies produced in this way are exact impressions of the hob. This improvement over the original method is the chief reason for the indispensable position which die hobbing now holds in mold building.

Advantages of Method.—The exact duplication of dies which is inherent in this method of production is in itself enough to justify hobbing for precise die work. Such precision is no more than approximated by ordinary machining methods. Also, multiple dies can generally be produced at less cost by this method, depending upon the cost of the hob and the number of dies over which this cost may be distributed. In addition, dies produced by machining may require being made up of several parts. Such construction is not recommended and may be avoided by hobbing. It is quite possible that a single die cavity may be an intricate and laborious machining problem. The machining of a hob, however, may be very simple for the same case and allows unlimited and rapid duplication of dies. Speed of production may be as important as low cost, on occasion.

Preparation of the Hob.

Material.—The hob may be made of any high-grade tool steel of high-carbon content and fine-grain structure. Since the compressive stress may occasionally be as high as 200 tons per square inch, it may be seen that the hob must survive very severe use. For unusually severe

service special steels may occasionally be selected, while for the more common cases of compressive stresses up to 100 or 125 tons, ordinary high-carbon steels are suitable.

Referring to Fig. 51, which illustrates a very simple form of hob of diameter A and length B, the hob proper may be considered the working portion which is to enter the blank. The butt consists of the larger remaining portion of the original stock. In forming the hob to the size and shape of the piece to be molded, a primary consideration is a slight draft or taper. This not only allows the hob itself to be more easily removed from the blank but also facilitates ejection of the finished molded work. Very rarely, the sides must be vertical. The hobbing of such dies is still a possibility, but is extremely difficult and requires a great deal of experience. The draft C for the usual case varies with the ratio of B to A. For shallow dies this may be 1 deg. When A and B are approximately equal, the draft may be 2 deg., while for deeper dies 3 deg. is satisfactory.

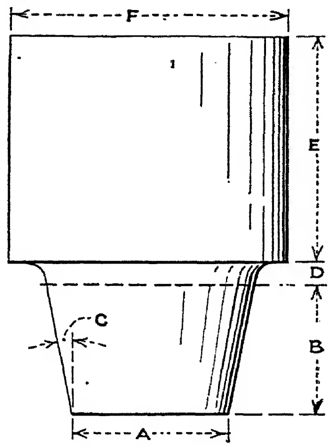

FIG. 51.—Hob.

The working depth B is usually made $\frac{1}{8}$ to $\frac{1}{4}$ in. greater than actually required to insure full depth. It may be noted that the butt diameter F is considerably larger than the hob proper. This is of no particular consequence when hobbing without a chase ring, in which case the butt may merely continue the size of the hob. When the hob is to be used in a chase, however, the butt must act as a guide in the bushing and must be made to fit the most suitable ring available. Since the rings are expensive, only a few sizes are ordinarily on

hand, and the hob may have to be made from relatively larger diameter stock. The length E is roughly made equal to F when F is a diameter, or equal to the width, if the butt is rectangular in plan. The latter case occurs most frequently when no chase ring is used but is not limited to this situation. The butt should be ground to a sliding fit in the chase, where so used, and in any event the base should be ground exactly parallel with the plane of the face. The neck at D may be ⅛ to ¼ in. and should be filleted with as large a radius as convenient.

Shrinkage.—The matter of die shrinkage previously mentioned may be of importance for extremely precise dies. In this case, allowance must be made on the diameter A or corresponding dimensions of a rectangular hob. Since this allowance varies so greatly, depending upon the steel used for the dies, the determination of it presupposes some experience with the particular steel in question. In general, the shrinkage is practically proportional to the diameter of the die and for machinery steel dies amounts to perhaps 0.004 in. per inch of diameter.

Engraving.—Surface designs on the hob may be accurately impressed in the blank. These designs may be figures cut in relief or engraved in the face of the hob. Lettering is common and is best engraved on the hob. The depressed lettering resulting on the molded piece is not only more durable, but permits the use of an engraving machine for lettering the hob. Hand-cut lettering may be no more expensive and may be as satisfactory as that mechanically engraved. However, relief designs or lettering may be unavoidable. In this case the design may be cut by hand, or a double hobbing may be used.

In the latter case, a negative hob is first prepared, with the design or lettering engraved. This secondary hob may be used to raise the required figures on the

master hob. Since tool steel has poor cold-flow properties, this requires that the master hob be thoroughly annealed. Even with this precaution, it may be said that while this method of double hobbing is perfectly feasible and dependable within limits, its application is limited to the transfer of surface designs only, unless in the hands of experts. If no chase is used, well-annealed tool steel may require 75 to 125 tons per square inch to hob, depending upon the depth of figure or design. In a chase the same steel may require 150 to 200 tons, but since tool steel is poorly suited to deep hobbing, a chase is seldom needed.

If the sides of the hob taper appreciably, surface designs may be used here, just so long as the hob is withdrawable from the blank. The slight draft given to otherwise vertical side walls is not sufficient to permit side-wall decoration, except for reeding or fluting which, running parallel to the axis of the hob, offers no interference. Where side walls are decorated, the hobbing may best be done in a chase ring.

Polishing.—The shaping of the hob is followed by the major polishing operation. This is slow and tedious work and as a result is apt to be a focus of false labor economies, unless its importance is appreciated. Thus, not only is the shape of the hob impressed in the blank but the character of the surface as well. A perfect polish on the hob reduces polishing of individual dies to little more than a cleaning operation after hardening. The intimacy of surfaces is so complete between hob and blank that even a pencil mark on the polished hob may be transferred to the die. With such faithfulness of reproduction, it may be readily seen that a poorly polished hob is an ultimate extravagance in the subsequent labor required to polish the individual dies.

Hardening.—The hardening of the hob is essential to prevent deformation under pressure. While the partic-

ular operation is dependent upon the steel used, it may be said that it is more exacting than most hardening operations and requires greater care. The finished hob is used practically glass-hard, and it is good practice to immerse the hob in hot oil at 350° F. and quench to relieve some of the internal stresses. A very light polish to remove traces of the hardening operation is all that is required to make the hob ready for use. Any oil or grease used to protect the polish surface must be entirely removed before hobbing.

Preparation of Blanks.

Material.—As mentioned previously, mild machinery steel is the material most generally used for dies. While the grade of steel used makes little or no difference in the production of dies by the machining method, it is of great importance if the dies are to be hobbed. Mild machinery steel has good cold-flow properties, takes a sharp impression from a hob, is inexpensive and generally suitable. If the hobbing presents difficulties owing to great depth, a softer grade of steel may be used. In extreme cases, such materials as Swedish, Armco, or Ingot irons may be required.

In the other extreme are the various grades of tool steel, poor in flowing qualities and ordinarily difficult to sharply impress with the hob. While it is seldom required to hob dies of such steels, it is often advisable to hob a surface design in relief on a master hob from a specially prepared negative hob. While such cases are relatively simple, it is also possible with some difficulty to hob dies when more than ordinary precautions are observed.

Size and Shape.—The die blanks are usually circular in plan. This frequently allows the greatest economy in material, offers the simplest machining preparation, and, in most multiple-cavity molds, is the simplest shape

of die to hold in place. In addition to this, if the hobbing is to be done in a chase, this disk form is most easily prepared to fit the cylindrical hole of the chase and for this purpose should be ground to a sliding fit. Since it is in this case confined, its diameter need only be large enough to give the required wall thickness plus whatever excess may be required to allow for subsequent machining, depending upon the method of fastening in the mold.

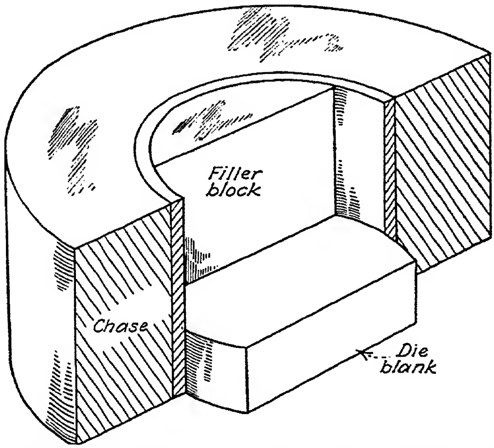

Fig. 52.—Hobbing of die blanks in chase, when blanks are not circular in plan.

Occasionally dies are to be hobbed which are relatively long and narrow in plan, but which for reasons of precision require use of a chase. To avoid the excess of material inherent in a disk of sufficient diameter for such a die, the blank may be of the same general proportions as the die cavity. In this case, the ends of the blank are circular in plan, to fit the chase. The spaces between the long straight sides of the blank and the chase are filled with two hardened-steel blocks which extend to the top of the chase. These prevent spread of the die blank and in extending to the top may serve as guides for the butt of the descending hob (see Fig. 52).

For blanks hobbed without a chase, the lateral flow of metal is a problem which depends somewhat upon the excess of metal around the hob and the shape of the hob proper. In most cases an excess width around the proposed impression equal to the working depth of the hob provides sufficient material to avoid undue spread. At the same time, spread may also be reduced by relieving the back of the blank. In doing this, 75 to 90 per cent of the volume of metal to be displaced by the hob may be machined out, in the approximate shape of the impression to be made in the opposite face. As the hob enters the blank, the die metal will displace at a lower pressure than if the blank were solid, and the tendency will be for the metal to flow down, rather than laterally. This method is frequently used in hobbing relatively shallow dies without a chase, when the hob is started into the plain flat surface of the blank (see Fig. 53).

Since the soft metal under the hob condenses with increasing displacement, it is not possible to sink the hob to any depth in a plain blank at one pressing. The only remedy for such a case is to anneal the blank repeatedly between successive pressings until the proper depth is reached. This is generally found unsatisfactory, since ridges are left on the side wall of the die at each separate pressing and are difficult to remove. To avoid this it is customary, whether hobbing with or without a chase, to prepare a cavity in the blank for the hob to enter, unless the hobbing is very shallow.

When the ratio of depth to diameter (or to the lesser dimension of a rectangular hob) becomes about one to four in small cavities, it is customary to assist the hob with a machined cavity in the blank. In larger dies it is found that regardless of this proportion, and especially if the hob is flat on the face, a feasible depth for a single pressing in mild steel is about ½ in. Thus all dies of

over ½ in. depth and smaller dies in the proportion mentioned above are initially prepared with a cavity for the hob. Relieving of the back of the blank is generally dispensed with in such cases. The cavity provided is the general shape of the hob but smaller by perhaps 25

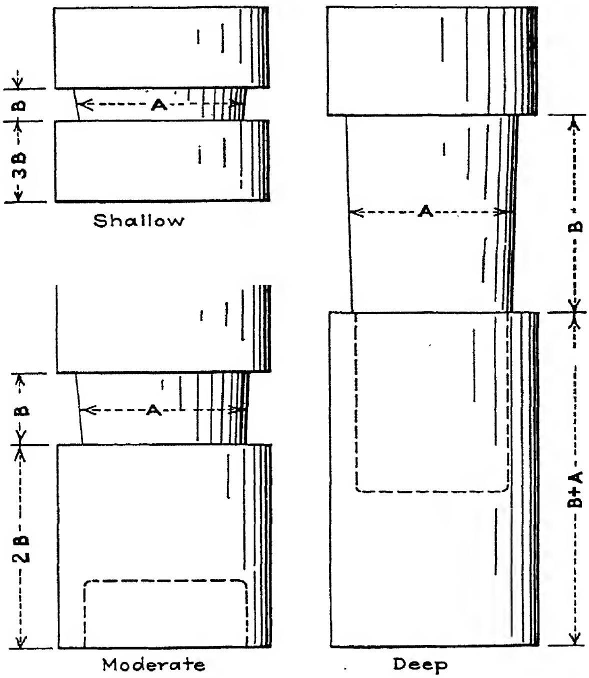

FIG. 53.—General proportions of hobs and blanks, for use in chase.

per cent volume, leaving some metal still to be displaced. If the axial section of the hob presents a complicated outline, this is simplified as much as possible in machining the cavity to receive it. Likewise, if the hob carries small projections beyond the main face, these may be neglected in machining the bottom of the cavity. The inside of the cavity in contact with the hob requires polishing before hobbing. This is also to be observed

in hobbing a flat blank, which requires polishing where contact with the hob is made.

The original thickness of the die blank is a variable, depending upon the size and shape of hob. With small ratios of B to A (Fig. 53), perhaps up to ½, the depth may be $3B$. With ratios from ½ to 1, the depth of blank may be twice the depth B. With ratios greater than 1, the depth of blank may be equal to the working depth of the hob plus its diameter, or B plus A.

Annealing and Polishing.—The bottom face of the blank does not require a fine finish but is usually ground to insure a good bearing. Polishing of the upper face or prepared cavity is best done after annealing. A thorough annealing is essential to insure maximum flow of metal, and this, with the polish mentioned above, completes the preparation of the blank.

The Hobbing Operation.

Equipment.—The hobbing of the blanks may be done in any hydraulic press of sufficient tonnage and of proper design to withstand a concentrated load. Presses designed for the purpose are fitted with hardened-steel anvils to distribute the load over the platens and in having relatively small platens are most convenient to use. In any case, a pressure gage is indispensable for the operation, while a depth gage to indicate the position of the hob is sometimes convenient. Hobbing presses are ordinarily direct-connected to a high- and low-pressure pump.

Pressures.—The hob may be sunk at a slow speed of ½ to ¾ in. per minute. The total pressure required cannot be determined precisely in advance but closely enough for practical purposes. Thus the softest steel or iron may be hobbed at pressures as low as 50 tons per square inch if not confined. If a chase is used, the pressure required is practically doubled.

Press Operation.—To follow the progress of the operation, a hydraulic pressure gage is important. The anticipated final reading will not appear as soon as the full face of the hob enters the work, but progressive building up of the pressure with fluctuation of the gage needle indicates proper progress of the work. A sudden rise in pressure indicates either that the hob is sunk to a depth at which the shoulder interferes or that the metal under the hob has condensed. Needless to say, the press must be stopped immediately in either case. If

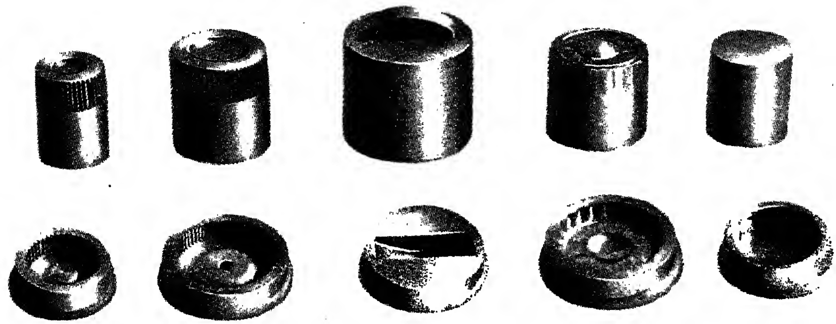

FIG. 54.—Hobs and dies produced from them.

the hob has not sunk full depth, the die may be annealed and pressed again. As previously mentioned this is to be avoided whenever possible by taking precautions in preparing the blanks.

Considering the destruction which may be done by a hob shattering under pressure, it is inadvisable to directly watch the progress of the work. While a depth gage is often found on the large machines, occasionally a steel plate, carrying a small window of safety glass, is used as a guard in front of such a press.

Finishing of Dies.

Machining.—The machining operations connected with finishing the hobbed blanks consist of removing

excess metal provided in the blank and providing for retaining and for special pins. It may be expected that facing the dies will require removal of considerable stock. This arises from the drawing down of the metal around the edge of the cavity and varies depending upon the steel and method of hobbing.

Hardening and Polishing.—The subsequent finishing of dies consists of pack-hardening, as previously described, followed by light polishing or cleaning to remove scale. No major polishing operation is required, since the dies are produced with the same polish as found on the hob.

PART III

OPERATING EQUIPMENT

CHAPTER VIII

MOLDING PRESSES

Hand-molding Presses.

Owing to the desirable operating characteristics and inherent simplicity, hydraulic presses have been the natural choice for plastic molding since the beginning of the industry. With the exception of a relatively few mechanically operated presses, chiefly of the toggle variety and rack and pinion type, hydraulic presses may be considered standard press equipment for general molding. While the simplest form of press was used for some seventy years without appreciable change, great improvements have been made in design in the past twenty years. This has come about with the introduction of the newer plastics and the general demand for greater production which has forced the elimination of manual labor wherever possible.

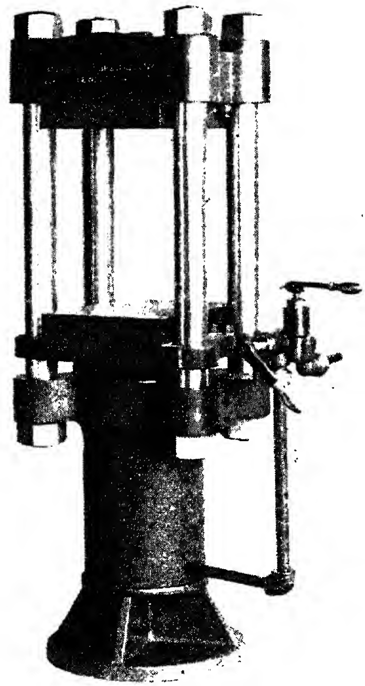

FIG. 55.—Rod-type hand-molding press.
Opening between platens here is greater than usually used.

Figure 55 illustrates the very simple type of press upon which the molding of rubber, shellac, and pyroxylin

products was based. While this type of press continues in use at the present time in the molding of these same plastics and has been applied to the newer molding materials, it is relatively unimportant in this latter field.

The low first cost and maintenance charges recommend such a type of press, where the capital investment must be small and where labor charges are low. In the high-production thermosetting plastic field, such a press is no longer considered as production equipment, although found desirable on occasion. Small, custom-molding shops may still find such press equipment suited to their needs.

The simplicity of this press allows for only slight variation in details in the various makes on the market. Perhaps the chief difference of importance to the user is the manner of packing the cylinder. A cup or U packing on the bottom of the ram is generally considered the most convenient to replace. Occasionally such presses are packed by means of a U packing located in an annular groove or throat in the cylinder wall near the top. Such construction permits some manufacturing economies, but the packing, especially in a small press, is sometimes troublesome to replace. Some improvement on this may be found in a stuffing-box and gland arrangement.

Rod Presses.—Rod presses, such as shown, require occasional adjustment to maintain proper alignment of platens. This generally results from eccentric loading, with consequent unequal straining of rods and loosening of nuts. For general molding purposes, presses of this type seldom have a fixed opening, since variation in the thickness of molds requires some latitude in this regard. Thus it is customary to employ presses with a maximum opening which may be reduced as desired by adjustment of the upper platen on the rods.

The platens of such a press are seldom cored for heating but are preferably solid. Separate steam plates may be mounted on these platens, backed with asbestos insulation or with such insulation in addition to a supporting and insulating grid. The practice in America is to provide the steam plates with a smooth working surface, as distinct from the T-slotted heater plates sometimes

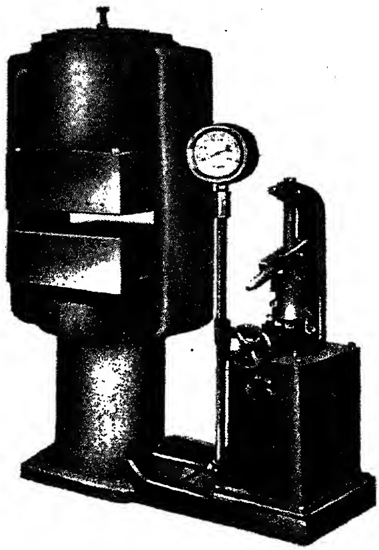

FIG. 56.—Rodless-type hand-molding press with hand pump.

used abroad. While the use of slots permits a mold to be easily fastened in the press, such presses are not suited to this service and in this country, at least, are not employed. Hence, with the custom here of manual handling of molds used with such equipment, the general term of hand-molding press applies to this and all similar press units. The particular press shown is intended to be operated from a central hydraulic system and requires no more than a simple stop and release valve for control.

Rodless Presses.—Figure 56 illustrates another type of hand-molding press used in the same capacity as the one previously shown. In this so-called rodless type of press, the head, stanchions, and cylinder may be cast as a unit, to give a rigid construction. This cast-steel frame is machined at one setting and maintains proper alignment of the press parts. While the cylinder of the press shown is fitted with a copper liner to prolong the life of the packing, this is a feature to be preferred in practically any molding press, regardless of type. In the press shown, a decrease in the maximum opening is obtained by means of parallel spacer rings, which may be slipped in place under the head.

The hand pump shown mounted on a common base with the press is in no way an essential part of the press but provides a self-contained unit, independent of the usual central hydraulic system. In using a hand-pump unit, manual operation of the pump lever raises the press ram at fair speed until the press is closed. The resistance then being too great, the low-pressure plunger of the pump is locked out of operation, while the required pressure is easily obtained with the smaller diameter high-pressure plunger. The pressure may be varied to accommodate various sizes of molds in the same press. This convenience is not easily obtainable where presses are operated from a central hydraulic system and is an advantage in a small plant.

Figure 57 shows still another hand-molding unit, in which the former hand pump is replaced by a power pump, to reduce operating time and effort. The high- and low-pressure pump is automatically controlled, while a small accumulator permits change of tonnage by a simple shifting of lever-arm weights. As in the hand-operated unit, the same water is used repeatedly. Either type of unit is entirely independent when equipped with electric heater plates and may thus be operated when the

rest of the plant may be shut down, as during week-ends, overtime, or night work. So equipped, either type of unit is particularly suited to laboratory use, where variable tonnage is desirable.

Size.—There is no standard tonnage or size in hand-molding presses, this depending upon the nature of the

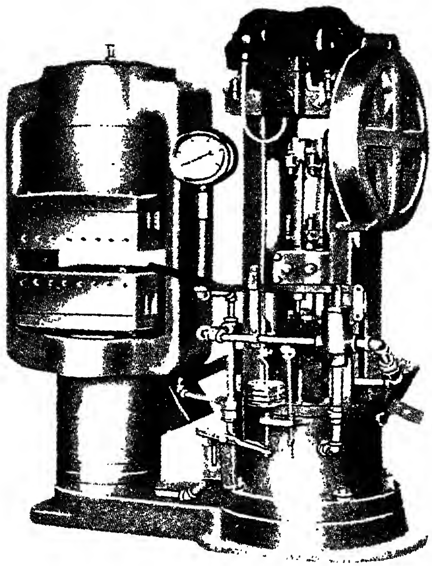

FIG. 57.—Rodless-type hand-molding press with individual motor, pump, and adjustable accumulator.

work to be done. Yet it may be significant to observe that for custom or job molding, the 75-ton press is more used than any other. For this press, 16 by 16-in. platens are usually preferred. A maximum stroke of 6 to 8 in. and a maximum opening of 8 to 10 in. are ample for general molding work. Multiple-opening presses are not used for molding purposes aside from the production of rubber goods.

Semiautomatic Presses.

Features.—The first type of press developed to meet the demand for improved equipment was the semiautomatic, introduced some twenty years ago with the advent of the newer plastics. This press permits the permanent mounting of molds, the positive opening and closing of molds, and positive ejection of the work. In requiring the manual loading of molds and removal of ejected work, such presses are not fully automatic but, especially in the later designs, represent the feasible limit of automatic operation for present-day purposes. The utility of the semiautomatic press allows the great majority of molding problems to be handled by it. It is thus considered the general-purpose production press, as distinct from some of the later special-purpose machines.

Inverted-ram Press.—Figure 58 illustrates an early design of a semiautomatic press still in wide use. In this the chief improvement over hand-molding presses lies in the secondary or pull-back cylinder used to return the movable platen to its initial position. By this means power is available for the separation of the dies after each molding operation, as well as power for the ejection of the molded work. It may be noted that the main cylinder is located at the top of the press, requiring the upper platen to be movable. This feature is incidental, since in presses of small size or short stroke the ram may be located at the bottom. However, in large presses, pit or platform mounting may be avoided by use of such inverted-ram machines.

The movable platen is conveniently guided by the rods but is given a lateral clearance of about $\frac{1}{32}$ in. The main ram is relatively short and is usually packed by means of a U packing located at the end of the ram. The pull-back cylinders are provided with a cup or U packing as required.

Where head room is limited, the pull-back cylinder is sometimes dispensed with in favor of two push-back

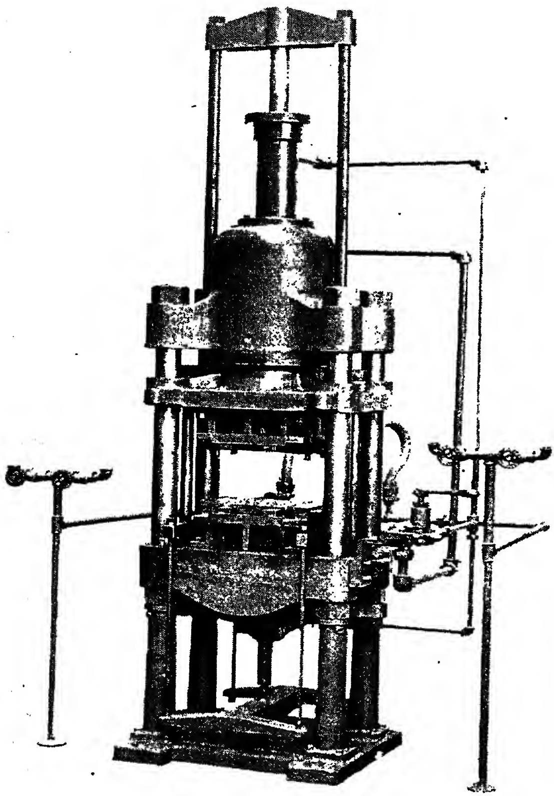

Fig. 58.—Semiautomatic inverted-ram press. Upper platen elevated by pull-back ram, at top. Note small stripper cylinder, and frame under lower platen.

cylinders of equivalent combined tonnage, located between the side rods of the press.

In either case, the secondary cylinders are at all times under line pressure, the press thus returning to its initial position as soon as the high-pressure water is released

from the main cylinder. Since these cylinders are opposed, the net tonnage available for molding is less than the power of the main ram by the pull-back capacity. In presses of the design shown, the pull-back

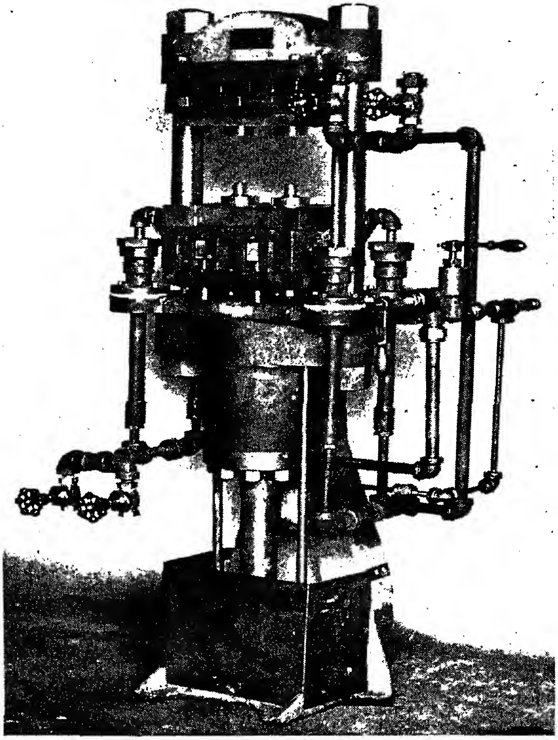

FIG. 59.—Small semiautomatic press with lower platen movable. Note slip-joint steam connections to lower dies, and steam and water valves.

capacity is generally 10 per cent of the net tonnage of the press.

Ejection.—With all semiautomatics of the style shown the method of ejecting the work is essentially the same. Thus vertical ejector pins are incorporated in the design of the mold, being in the upper dies, except in special cases. These pins, normally setting flush with the

molding surface of the die, may be projected to expel the work. In the case of upper ejector pins the upper dies ascend, carrying the pins in normal position. When the upper platen has almost reached its initial position, the ejector pins strike a fixed stop while the platen continues to move to the end of its stroke. Unless a special device is used to reseat the pins, they will be in a projected position each time the mold closes. In operating ejector pins in the lower dies, since the lower platen is fixed, the motion must be taken from the upper platen by means of rods. These rods, not rigidly attached, pick up the motion of the upper platen near the end of its upward stroke, lifting the ejector frame under the lower dies, and the ejector pins. Left in this projected position, these pins are more objectionable than when in the upper dies, since they may interfere with proper loading of the mold. To avoid this condition a special retracting device may be applied. The illustration shows such an accessory, called a stripper cylinder, located under the lower platen of the press.

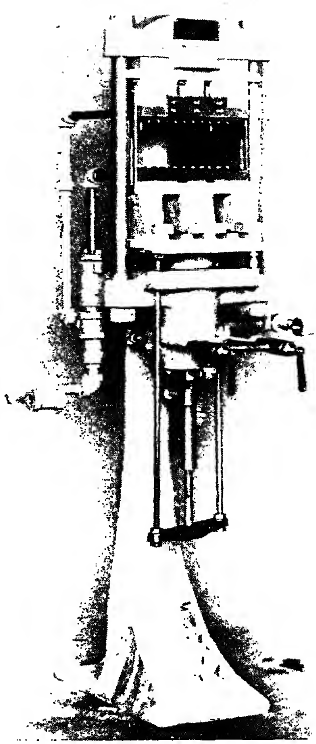

Fig. 60.—Very small semiautomatic press particularly useful for laboratory work.

Platens.—The early semiautomatics as illustrated, were designed with platens either square or very nearly

so. Subsequent experience has shown that from the standpoint of production this is not the most efficient shape for multiple-cavity mold operation. Hence, in later designs the platen length from side to side of the press has been considerably increased, while the distance from front to back has been reduced. The attendance time and effort are reduced by this design. However, for large single-cavity molds or for molds having relatively few but large dies, the square platen press is still entirely suitable.

Improved Presses.—Figure 61 illustrates one of the most improved types of semiautomatic presses incorporating practically all features which may be demanded in a modern molding unit of this type. These presses are made with either a movable lower platen or with the inverted-ram construction. In the latter case a single inverted cylinder may be used, or two main cylinders may be located between the side rods of the press, to leave the upper head clear for the application of a central top ejector cylinder. At present, the preference seems to be for a press with lower movable platen as shown. In this case, push-back cylinders located between the side rods open the mold and return the ram to its initial position but serve no other purpose.

Ejection is independent of the pull-back cylinders and for the usual case is effected by means of a differential cylinder located on the top head. Thus the ejector is positive in operation, in either direction, and may be operated at any point of the stroke. The same may be applied to the lower platen, although for this case, to avoid the centrally located ram, it is ordinarily necessary to use two ejector cylinders.

In either case, the ejectors actuate master ejector bars running from front to back at the ends of the mold. These bars, properly designed, allow for the adjustment of transverse bars, as needed to suit the ejector pins of

individual molds. Thus the former need of a special ejector frame or grid for each mold is eliminated. To avoid undue deflection of the transverse bars and possible binding of ejector pins, a third master bar is pro-

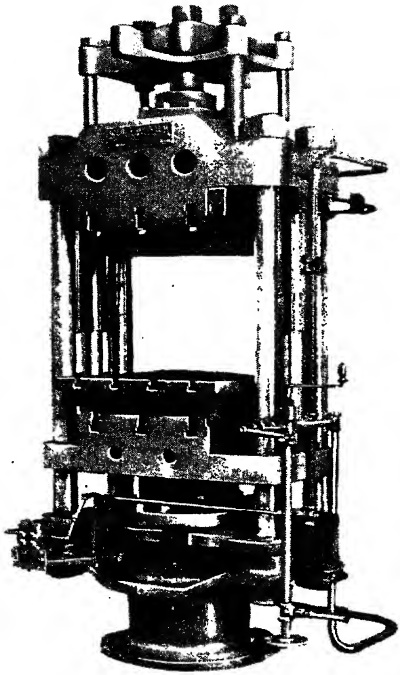

FIG. 61.—Modern semiautomatic press. Note arrangement for bolster mounting of mold, push-back cylinders between side rods of press, and independent double-acting ejector cylinder at top.

vided in some presses, supporting the transverse bars at their centers and affording a rigid construction.

Double-acting Ejectors.—Positive, double-acting ejectors are not only more desirable than the usual type for ejecting purposes but extend the possibilities of the press for the operation of special molds. Thus the pull or

push-back feature formerly used for ejection is still available in these newer machines. Consequently this may occasionally still be used for ejecting, while the independent ejector may be used to operate a special mold part, such as a stripper plate. Incidentally, in deep molding where particularly heavy ejectors are needed, it is possible to combine the effect of the pull-backs and independent ejectors, to give approximately twice the normal ejector tonnage. Since the ejectors and pull-backs each have a nominal rating of 10 per cent of the net press capacity, this affords 20 per cent which should cover the most extreme cases.

Platens.—The platens provided are long and narrow, permitting the rear dies to be easily reached. The special grid usually required for supporting each mold is eliminated. Instead, two transverse bolsters are mounted on each platen, supporting the mold along the front and rear edges. These bolsters, being adjustable, may be spaced to suit molds of various widths which may conveniently be fastened down by gib strips. To avoid deflection of the central portion of the mold, transverse supporting parallels may be placed between the bolsters and between the transverse ejector bars.

Importance.—Modern semiautomatic presses, having in general the features mentioned, may well be considered the backbone of production molding equipment. The versatility of the improved designs permits probably 90 per cent of all molding problems to be handled in this type of press.

Standardization.—Unfortunately there is no recognized standard in tonnage or press proportions, although for years the 75-ton press of original design was most used. Present production demands have by no means excluded this size of unit, although the tendency is toward larger presses. From the equipment demands of the past few years, a logical series of press capacities

would appear to be 75, 100, 125, 150, 200, and 300 tons. It is to be hoped that manufacturers and molders may eventually enjoy the mutual benefits of such standardized equipment. To date there has been little effort along this line. In regard to ejector equipment, bottom ejectors are so seldom needed that they are not likely to ever be included as standard equipment. Nevertheless, proper press design should allow for the application of such ejectors for the occasional special case. Less standardization is to be expected in regard to platen sizes, than in press capacities, owing to the great variation of molding pressures required by different materials. In regard to materials requiring approximately 1 ton per square inch to mold, platen areas of 300 to 500 per cent of the net molding area have been found most suitable for general use.

Tilting-head Presses.

Purpose.—Within a few years after the introduction of the semiautomatic press, the more special tilting-head press was developed to satisfy the demands of insert molding. At this time it was common practice to mold inserts, in spite of the difficulty of loading molds and loss of production. While the lower dies were not particularly troublesome, there was need for a machine which would present the upper dies in a position more convenient for setting inserts and for inspecting the upper dies. The tilting-head press was designed for this particular purpose.

Design.—Figures 62 and 63 illustrate one of the later designs of this type of press, showing the fundamental principle employed in the first machine as well as later improvements. In the figures shown, the lower platen is actuated by two main rams in the cylinder block at the base of the machine. Space requirements made this preferable to a single large cylinder requiring a deeply

braced platen. The lower platen is returned by four push-back cylinders, two of which may be seen at the front of the main cylinder block. These cylinders provide ejection for the lower dies. The movable side frames, or stanchions of the press, act as links, pivoted on trunnions at the ends of the main cylinder block and

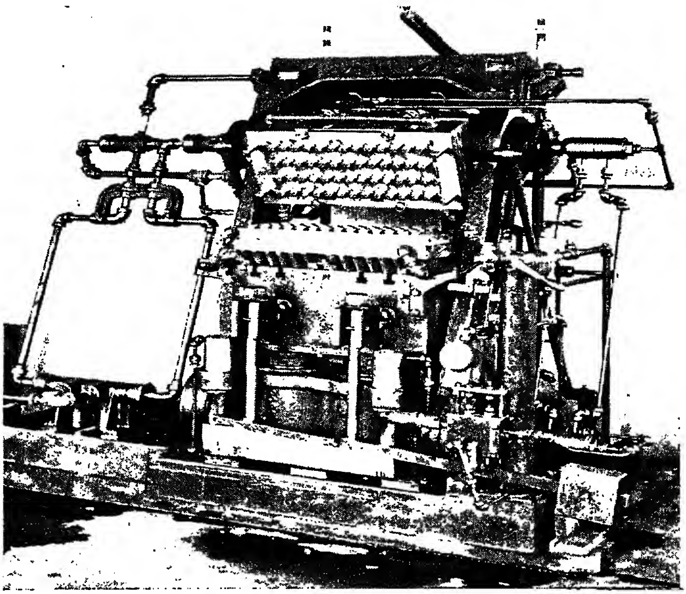

FIG. 62.—Tilting-head press in open position. Note accessibility of upper dies for cleaning and inspection. Ejection controlled by foot treadle. Press control valve at right. (*Watson-Stillman Co.*)

carrying the upper head by similar trunnions. When the stanchions are swung back, by means of the hydraulic tilting cylinder, the head not only follows in an arc but is also turned through 90 deg. This is accomplished by means of operating rods pinned to the bed plate and to the head. As shown in Fig. 62, this presents the upper dies in a vertical plane at the rear edge of the lower platen, permitting free access for cleaning or inspection

and setting of inserts. Positive ejection for the upper dies is provided by four ejector cylinders on the tilting head, in the design shown.

When alternate heating and chilling are required, a hydraulically operated steam and water valve is located at the left of the press on the bed plate. Steam con-

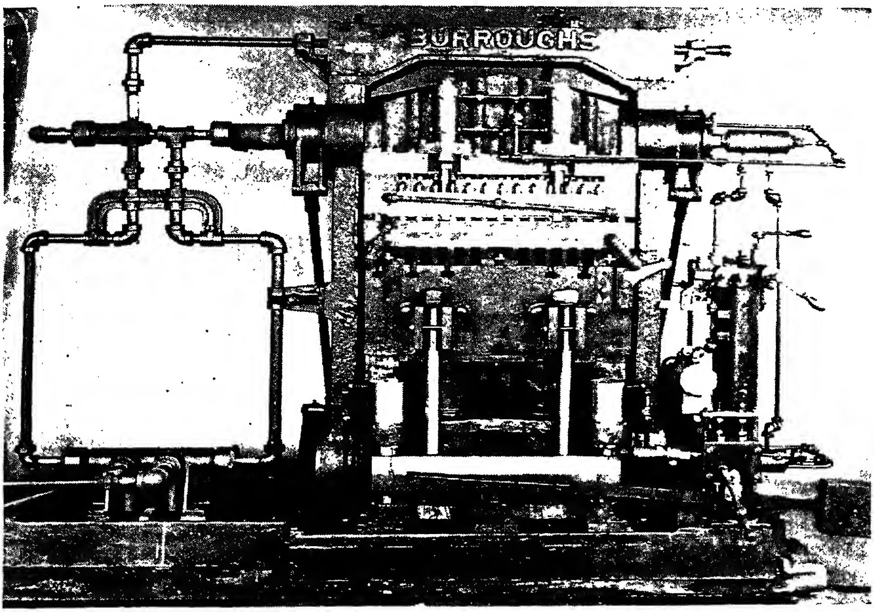

FIG. 63.—Closed position. Note two of four ejector cylinders on top head, also two of four push-back cylinders for lower platen. Special steam and water valve may be mounted at left when desired. (*Watson-Stillman Co.*)

nections to the lower dies are made by means of slip joints, while the upper dies are reached by piping extending from a stuffing box axially aligned with the lower trunnions to a similar joint on a trunnion of the tilting head.

Advantages.—Having been developed particularly to facilitate insert molding, tilting-head presses may be considered special-purpose equipment. Yet the inci-

dental advantages of this type of press have frequently led to its selection even for general molding. In some cases, the visibility and accessibility of the upper dies are alone considered sufficient to justify an installation. In addition to this, relatively little motion of the ram is required to permit operation of the head. This allows a short stroke, with consequent economy in use of high-pressure water.

There are several presses of the swing-top or hinge-top design on the market, affording some of the advantages of the press shown. In the smaller sizes, the head may be operated manually on such presses without undue effort. Larger machines requiring mechanical operation of the head are available but are not so extensively used as the smaller units.

Size.—Until the last few years, tilting-head presses of the type shown were used almost exclusively in a 75-ton size. As in the case of semiautomatics, the trend is toward larger units at the present time. Presses of 125 and 150 tons, of the type shown, have been in use for several years.

Angle-molding Presses.

Purpose.—The angle-molding press was introduced shortly before the tilting-head unit, to make possible the press operation of three-part or split molds. Such molds were previously limited in size because of hand operation and were low in production owing to the time required in unloading and assembling.

Design.—Figure 64 illustrates one design of angle press using rodless construction. The press frame is a single steel casting, in this unit affording a compact, rigid construction. However, presses both larger and smaller are made with sectional frames, this being particularly desirable in the large machines as a matter of convenience in shipment.

Both horizontal and vertical cylinders are provided, operating platens which are returned by pull-back rams. This affords positive ejection of exactly the same type as in the early semiautomatic machines and has proved adequate for all ordinary angle-molding needs. Inde-

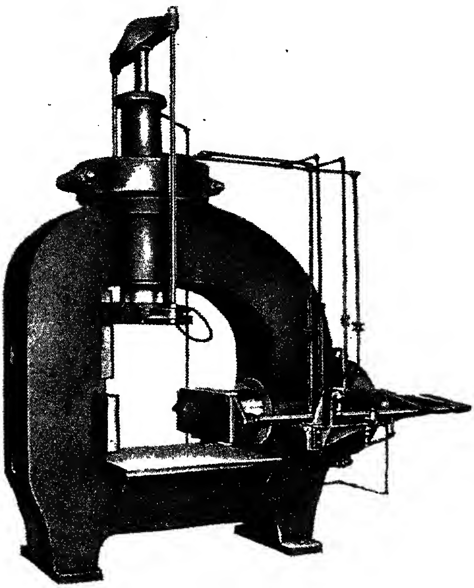

FIG. 64.—Angle-molding press of rodless type. Note pull-back cylinder for each main ram, and absence of separate ejector cylinders.

pendent hydraulic ejectors have never been applied to this type of press.

It may be noted that the main cylinders of the press shown are of the same size. Since the projected die areas of the parts operated by the cylinders are seldom equal, this appears incompatible with the requirements. Analyzing split-mold operation, it will be found that the horizontal cylinder generally brings together the two main parts of the mold before loading and merely locks these in contact during the molding operation. The

vertical cylinder, on the other hand, usually operates a core piece of relatively small size which is used as a displacement plunger after loading. Since the material,

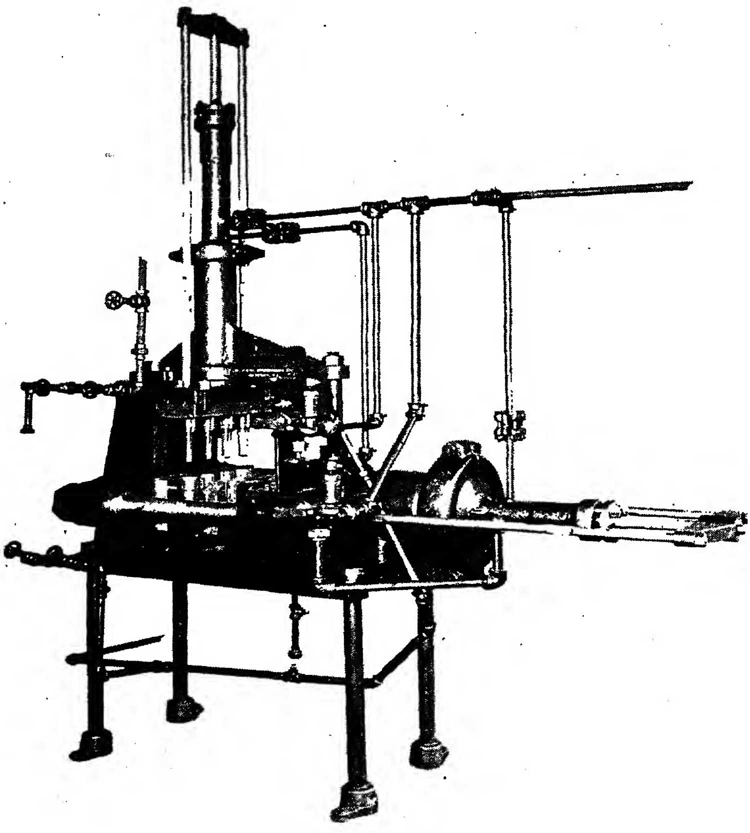

FIG. 65.—Angle-molding press of rod, or sectional, type. A more common type of construction, regardless of press size.

when plastic, does not exert uniform hydrostatic pressure in the mold, a relatively greater force is required to operate the displacement piece of the mold. Thus, while main cylinders of equal size are not correct for all split-mold operation, such design best satisfies the aver-

age requirements and covers the greatest range of usefulness.

Application.—Through the use of special auxiliary cylinders, it is possible to operate split molds of more than three parts, but this is to be avoided whenever possible. The practice of applying auxiliaries to semiautomatic presses for the operation of split molds has grown since the introduction of the angle press. Such practice permits the solution of an occasional split-mold problem without the use of a special press and has proved satisfactory where the special device is relatively small in size. Since the rods of an ordinary press are not designed to withstand a lateral force, special cylinders of large size may require special bracing or opposed cylinders. Such special devices may become so cumbersome as to leave insufficient working space for the operator. In such cases, the angle-molding press has its special field to itself.

Size.—Angle-molding presses are used in a great variety of sizes, with no particular size predominant. While they have been made in sizes ranging from 10 to 400 tons, the 140-ton press shown in Fig. 64 is still considered a large machine.

Mechanical Presses.

Mechanically operated presses resembling hydraulic semiautomatic machines have been introduced for the molding of thermosetting plastics. In the most successful of these machines the movable platen is operated through a rack and pinion driven by an electric motor. Push-button control is provided for the unit, in which the tonnage may be varied to suit the mold requirements.

Such molding units have the virtue of being self-contained and independent of a hydraulic system. As previously mentioned, a most desirable characteristic of a hydraulic press is the following-up of the movable

dies as the molding material becomes plastic. The chief difficulty in mechanically operated presses is to approximate this same operation. If the motor is automatically cut out of operation when the mold encounters initial closing resistance, the unit must be restarted for final mold closure after the material has become plastic. In such a case, the additional attendance required over the hydraulic unit is not desirable.

While not necessarily limited in size, mechanically operated molding presses have been chiefly built in the smaller capacities, but can be furnished in sizes up to 300 tons or larger. In spite of the desirable elimination of the usual hydraulic systems, such presses are not widely used.

Miscellaneous Presses.

With the exception of the hand-molding presses, the foregoing machines apply primarily to the molding of thermosetting plastics. In many cases of the older plastics, the original equipment remains adequate to the needs.

Thus in the molding of soft-rubber goods, the molds are principally hand-operated, permitting the use of a simple type of press. Instead of the single-opening hand-molding unit, however, multiple-opening presses are employed. In the past, in hard-rubber molding the curing time has been too long to permit the investment in improved presses and press-mounted molds. Since the curing time has been reduced, it seems reasonable to expect that, as this more nearly approaches the molding time of the faster curing materials, such work may be more efficiently done in the newer machines.

Shellac molding has never progressed to improved equipment. However, through preheating of material and molds and absence of the curing period generally required such work can be turned out in large volume

with hydraulic hand-molding presses and mechanically operated toggle presses.

The blowing of pyroxylin sheet stock remains a hand-molding operation in which simple presses of very short stroke are used. As operated for the blowing operation, the press under nominal low pressure seals the edges of the stock. Subsequently, high-pressure water provides the

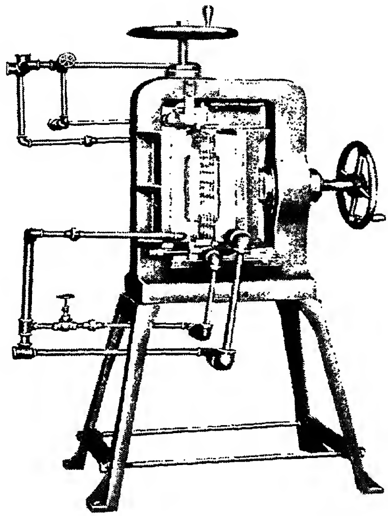

FIG. 66.—Hand-operated press for tube-blowing molds. Note upper manifold raised to clear ends of tubes. Lower manifold is moved horizontally to position midway between open dies and thus used as ejector for tubes.

necessary capacity for welding the stock and cutting off the excess. In the blowing of tube stock, the loaded mold, initially closed, may be held in a hand-operated screw press, as shown in Fig. 66. In the special operation called drawing, in which sheet stock is shaped in a way very similar to the drawing of sheet metal, small hand-operated toggle presses are used.

Laminated stock is produced in multiple-opening presses arranged for heating and chilling of the platens.

Ten to twelve openings are commonly used for such work. The size and shape of the platens required for such work result in presses of four, six, or even eight main rods and two or more main cylinders. Used for the surfacing of pyroxylin sheet stock, such machines are commonly called polishing presses.

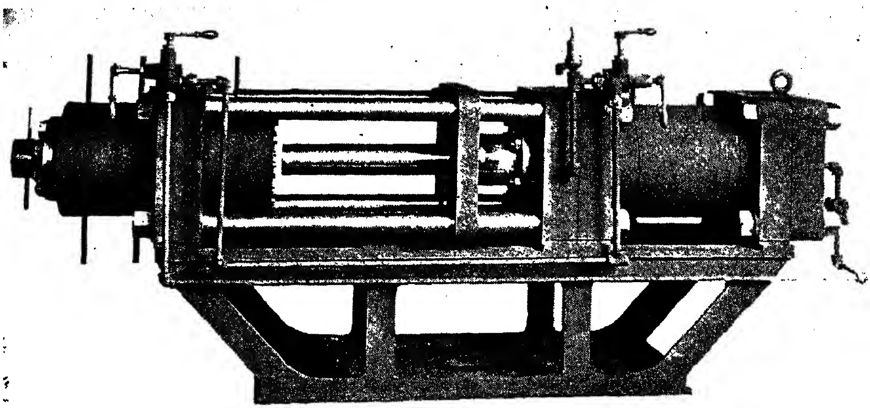

FIG. 67.—Hydraulic extruding machine. To the material cylinder at left may be attached nozzles to produce rod or tubing of various shapes. Material is kept plastic by means of steam-jacketed cylinder. Nozzle is jacketed for steam or cooling water. This machine is suitable for injection molding of fusible plastics only.

In injection molding, in general, the equipment consists of hand molds, a simple press, and an extruding machine, such as that used for rods or tubing (Fig. 67). With the application of injection molding to thermosetting plastics, special units have been developed carrying the extrusion cylinder and permitting press-mounting of the molds. The current interest in the injection molding of cellulose acetate has brought about similar machines for that plastic.

CHAPTER IX

ACCESSORY EQUIPMENT

Hydraulic Systems.

Hydraulic systems for the operation of molding presses are by no means standardized, but in the operation of large batteries of presses two distinct systems may be found.

High-pressure System.—The first and simpler of these is known as a high-pressure system. This consists essentially of a high-pressure pump and accumulator, with the necessary single line of piping to each press and control valves. The return line may be of standard weight pipe and returns the waste water from the press, either directly to a sump built into the pump or to a separate well. The new water required is merely that necessary to make up for leakage. Such a system has simplicity and relatively low installation cost to recommend it and for these reasons is still used.

High- and Low-pressure System.—A second type known as a high- and low-pressure system is more frequently found, especially in large plants. This dual system was introduced to the thermosetting plastic field some years ago in an effort to allow initial closing of the mold under nominal pressure to avoid bending of slender mold pins. The high pressure is applied for final closure of the mold, being thus used during a relatively small part of the stroke. This latter feature, offering economies in the use of relatively expensive high-pressure water, permits lower operating costs than the simple high-pressure system.

In comparing the two systems, the installation and overhead charges of the dual type are not to be overlooked. Thus the amount of piping required is nearly double that for a simple system, since the low- and high-pressure water must be separately piped to the operating valve at each press. In addition to this, if the press ram is to move at a desirable speed, large pipe is required for the low-pressure line. A much more expensive type of operating valve is required for the dual system. In large installations a low-pressure accumulator is used with pumps delivering at 150 to 500 lb. per square inch, preferably the latter. Obviously such a system is of doubtful economy in a small plant, but with larger capacities where the equipment cost is relatively less, such a system is advisable.

For smaller installations, avoiding the several separate pieces of equipment mentioned above, a single unit is available for the operation of such a system. In one such unit, all water is initially supplied by a centrifugal pump, at the desired low pressure. As high-pressure water is required it is supplied by a displacement pump actuated by the low-pressure water, operating as a continuous-acting intensifier. Such units require relatively little floor space and have proved quite satisfactory.

Small dual systems are occasionally arranged to operate with city water furnishing the low pressure directly. These are generally found unsatisfactory, as the pressure is seldom adequate and the cost of water is high, since all low-pressure water must be run to waste.

For operation of individual presses, especially for experimental use, hand pumps offer the greatest flexibility. While such operation is not suitable to any but hand-molding presses, it is still possible to operate a battery of such presses individually in this way with economy. One type of work making this desirable is small-quantity production with varying sizes of molds.

For this same use hand-molding presses are available with independent motor-driven pumps. Such units, carrying a variable-weighted accumulator in conjunction with the pump, permit considerable variation of load to accommodate various molds. Units of this type may be very desirable where unusual production requirements may demand overtime or part-time operation of a small part of an entire plant. To the same end, so-called "variable-delivery" pumps have been applied to individual presses within the last few years. The characteristics of such pumps appear ideal for this use.

Pressures.—In the foregoing, the term "high pressure" is entirely relative and refers to no definite line pressure. This results from the various branches of the plastics industry developing on arbitrarily established pressure standards. Thus a line pressure of 1800 or 2000 lb. is common in rubber plants, while 2500 lb. is found less often. Shellac molding employs pressures of 1000 to 1200 lb. The pyroxylin industry uses various pressures from 500 to 3000 lb. The commonest line pressure for thermosetting plastics is 3000 lb. With the pipe, valves, and fittings now available, this high pressure is probably less troublesome than the lower pressures were when established. While it would be a mutual benefit to the equipment manufacturer and buyer alike to have the various pressures standardized, preferably at 2500 lb., such a movement is not likely to occur owing to the great amount of equipment to be replaced. The 2500-lb. standard is recommended for all new installations, as offering fast operation and installation economies occasioned by commercial valves and fittings designed for this pressure.

Pumps.

Types.—Reciprocating pumps of two, three, and four plungers are used to furnish high-pressure water. The

three- and four-plunger pumps naturally provide the steadiest flow. The choice is generally based on capacity rather than type, as any one, of the proper size is satisfactory.

For the more rapid operation of single presses, high- and low-pressure pumps may be used. The press ram is actuated by low pressure during the nonworking portion of the stroke. When resistance is encountered, the low-pressure valves automatically trip out of action, allowing the stroke to be completed under high pressure. Hand pumps are most useful built in this way, although the shift from low to high pressure is manual in this case. The variable-delivery pumps may be set for the desired maximum pressure, the capacity automatically decreasing as resistance is encountered and the pressure builds up.

Drive.—The majority of high-pressure pumps are direct-connected through reduction drive to a motor. While the motor in this case runs continuously, the pump operates intermittently, being automatically controlled by the accumulator. Such pumps may be equally well operated from a main line shaft, but such installation is not common. Direct, steam-driven pumps are occasionally used for both high- and low-pressure lines. In the latter application the usual low-pressure accumulator may be dispensed with.

To provide a large quantity of low-pressure water in dual hydraulic systems, motor-driven centrifugal pumps are most commonly used. To derive the maximum operation from the low-pressure piping, a pressure should be established which will require the maximum safe working pressure of the pipe. If conditions permit the use of standard-weight pipe, a low-pressure system of 200 lb. may be used. Where greater speed or power is required, extra heavy pipe will allow a system of 750 to 1000 lb. While the first is naturally the cheaper,

either system worked to capacity will provide minimum piping expense for the particular conditions.

Accumulators.

Types.—The accumulators used in connection with hydraulic systems are of two main types: the original, weighted type, and the more recent air-weighted design.

The first type (Fig. 68) consists of a vertical ram loaded with cast-iron weights, working in a long barrel from which water may enter from the pump or from which the main line may be supplied. Where a fixed line pressure is to be maintained, the adjustable cast-iron weights may be replaced by a block of concrete, a tank filled with ore, or scrap. In any case, the unit as a whole is usually too heavy to be carried conveniently by a floor and is best located in a basement. So installed, the unit may be placed in a pit to gain head room.

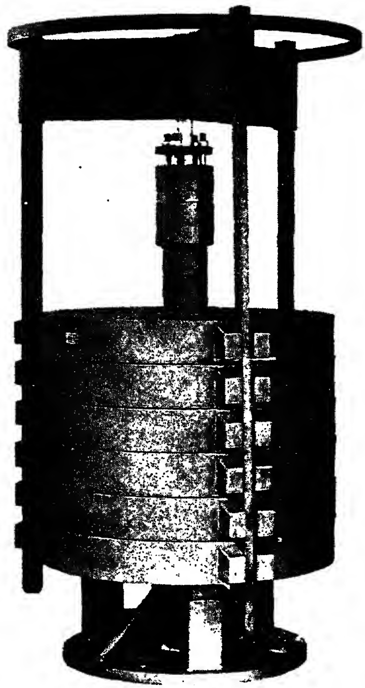

FIG. 68.—Weighted type accumulator. Moving ram, stationary barrel type. Line pressure variable in 500-lb. increments.

The more recent air-weighted type of accumulator (Fig. 69) consists of a barrel and ram similar to the former, but here the loading is accomplished by means of compressed air acting on a piston rigidly connected to the ram. Units of this kind generally contain a small motor-driven air compressor delivering air at about

200 lb. This may be dispensed with where other air supply is available. In either case, since the air is confined in the air cylinder of the accumulator, the new air required during operation is merely that necessary to make up for leakage. Since the air expands and contracts, depending upon the position of the ram, this

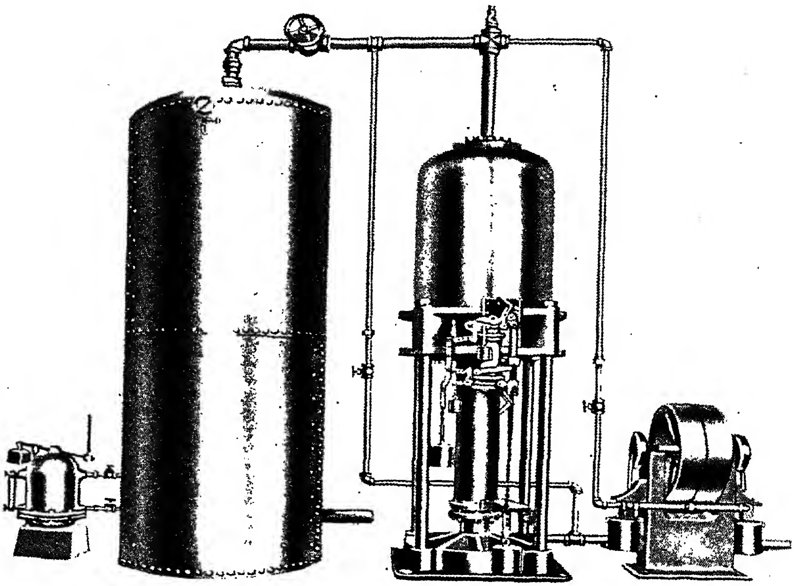

FIG. 69.—Hydropneumatic accumulator, including air tank and compressor. May be operated in horizontal position where head room is limited. Relatively light in weight. (*Watson-Stillman Co.*)

type of accumulator does not give the uniformity of pressure inherent in the other type, but for most practical purposes this is of no consequence. Such variation in pressure may be reduced to any reasonable degree by an air-pressure tank connected to the air cylinder. Accumulators of this type are relatively light in weight and do not require being located on a special foundation.

Accumulators for low pressures may be built with cast-iron or cast-steel barrels. For pressures of 2000 lb.

and more, and especially with units of the first type where stresses due to inertia effect may be very high, barrels should be steel castings. The better types carry a bronze lining in the throat, in conjunction with the stuffing box through which the ram passes.

Either type of accumulator must be made to control the action of the pump, cutting it definitely in or out as needed. The trips used for this may or may not be included as a part of the accumulator unit, but in any case they are essential for operation.

Piping and Fittings.

As previously mentioned, standard-weight pipe may be used for hydraulic waste lines, provided there is no obstruction to flow which would permit high-pressure water bursting the line if accidentally admitted. Since such diversion of high-pressure water may easily occur with the ordinary control valves used on presses, the waste line deserves consideration.

Low-pressure lines may be of either standard weight, or extra heavy pipe, depending upon the pressure established. Since most accumulators are made with an automatic bleeder which prevents pumping the ram out of its barrel, such a unit in the low-pressure line protects it against the admission of high-pressure water.

High-pressure lines may be made up of double extra heavy pipe, which provides an ample factor of safety when used at 2500 lb., which perhaps is a most desirable line pressure. Ordinary commercial pipe of this kind has been used at pressures up to 10,000 lb. for special work. With 10,000-lb. fittings now available, such lines may be operated safely. While pressures of this magnitude are not to be considered for the operation of molding presses, they are occasionally employed in the related field of hobbing.

Commercial fittings frequently exactly meet the pressure requirements, since for high-pressure work they are made in several weights. For 1500, 3000, 6000 and 10,000 lb. standard commercial fittings are available.

Valves.

Screw-stem valves are the commonest type used as press-control valves. For pressures up to 3000 lb. they are commonly made of bronze throughout, while

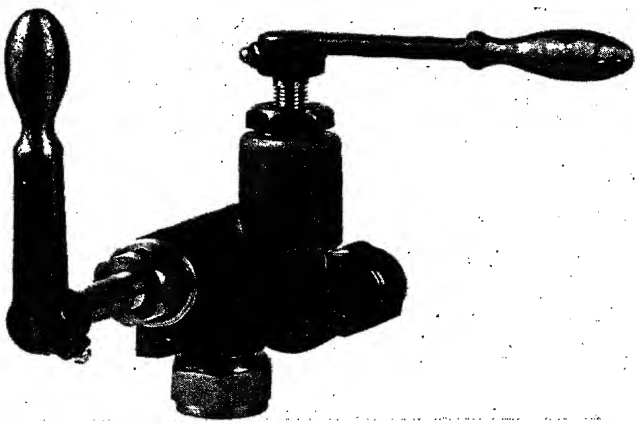

Fig. 70.—Plain stop and release valve required for controlling any single operation, such as of main ram, or ejectors.

for higher pressures a steel-bodied valve trimmed with bronze or monel metal is used.

The type of valve required depends upon the style of press it is to operate. The line from the valve to the press is both a supply and a waste line in turn. This requires a two-spindle valve to operate, which is ordinarily called a stop and release valve. The main ram of any ordinary molding press may be operated by a valve of this kind. Independent double-acting ejectors require a smaller, similar valve for operation of each ejector. While such valves may be had commercially, built for

various pressures, combination valves incorporating the separate controls in a single body are standard and are ordinarily designed for a particular style of press by the press manufacturer. Operating valves for high- and low-pressure systems are standard valves. Hobbing presses ordinarily operate with a "stop, check and release valve."

Standard operating valves may be applied to molding presses, in which the entire molding cycle is controlled by a single-control lever. This lever, swung through

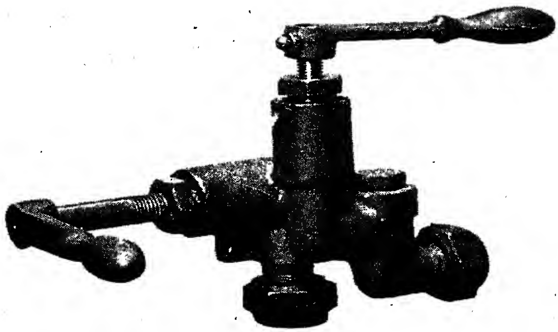

FIG. 71.—Stop, check, and release valve. Providing a safety measure in the event of failure of the main line pressure.

its arc, successively operates poppet valves admitting water to the various cylinders in proper sequence. Timing devices which allow a wide range of adjustment to suit various molding cycles may be used in conjunction with such valves, reducing attendance to loading and unloading of the mold. The expense for such equipment may be justified only when the attendance of more than one press by a single operator prevents the manual operation of ordinary valves.

The need of hydraulic safety devices is relatively small, since the main line is automatically taken care of by an accumulator of the safety type. One type of tilting-head press is provided with a special valve which prevents

operation of the ram until the head is in its proper position. Another special valve may be applied to any inverted-ram semiautomatic press and protects the operator from injury in case the ram would otherwise drop through failure of the high-pressure supply.

If alternate heating and chilling of the mold are required, two steam and two water valves are needed. To avoid the operation of four such separate valves, special poppet-type steam and water valves may be used with a single-lever control. If the sliding disk type of rapid acting valve is used, these may be linked together in pairs to obtain practically the same result.

Packings.

Packings for the main rams of molding presses are almost always leather, cup or U packings. Where the service is not especially severe, ordinary oak-tanned leather packings may be used with success. Such cases are presses kept continually cold, or presses used for heating and chilling if the molding temperature is relatively low. For plastics requiring a molding temperature as high as 350° F., chrome-tanned packings are recommended for either continuous-heated use or for alternate heating and chilling. While in principle it is very desirable to have no heat losses from the mold tending to heat the head, platens, ram, and packing of the press, such losses are not entirely avoidable. Mold insulation is generally given little or no consideration, with the result that packing costs are higher than necessary.

Leather U packings, carrying a hemp filler in the groove to retain their shape, are preferable to the plain type. A few presses are made with a gland and stuffing box at the throat of the cylinder. Such presses may be packed with square hemp packing, without the removal of the ram which is usually necessary with the other

packings. Since the friction loss is normally greater with hemp packing, such presses are occasionally converted to use of leather U packings when the movable platen is not integral with the ram.

The incidental packings required for pull-backs, ejectors, and special devices normally receive sufficient heat from the mold to warrant being of the best quality.

The steam piping to the movable platen requires a movable joint of some sort. Special swing joints usually require special packing designed for them. For severe service slip joints may be recommended rather than swing joints as giving at least as good service and also making a more sightly piping installation. Such joints may be packed with ordinary square steam packing. A shredded-leather packing is available which has been used with good results in this same capacity.

Stripping Presses.

Hand molding generally requires a stripping press for the separation of dies after molding. Where small low-powered hydraulic presses may otherwise be available, these may be used directly or converted with little trouble. Hand-operated arbor presses are quite satisfactory for this use and are relatively inexpensive. They should be of 10 to 15 per cent of the capacity of the molding presses with which they are used.

Tableting Machines.

Tableting machines automatically measure out the quantity of bulk material needed for the individual dies and compact the mass into a tablet or preform of desired shape and hardness. Aside from keeping the material hopper filled, such machines require practically no attention, after once being properly adjusted to the particular tablet to be produced, and may turn out as many as 600 tablets per minute in small sizes. A fair

production for tablets of about $1\frac{1}{2}$-in. diameter is 30 to 40 per minute, while 3-in. tablets reduce the rate to 10 to 15 per minute.

Two main types of tableting machines are available in several different makes and are equally satisfactory for the work. They are usually self-contained and carry a driving motor as part of the unit. Since there has been little demand for large tablets, the machines available are not suited to work of more than approxi-

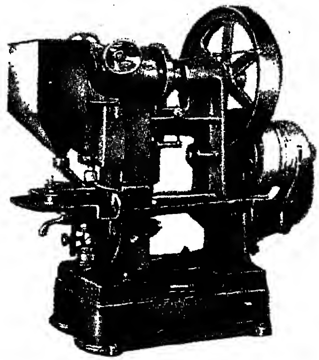

FIG. 72.—Single-punch tableting machine. Suitable for tablets to perhaps 3-in. diameter. (*F. J. Stokes Co.*)

mately 10 sq. in. of projected area. Within their limits tableting machines of the usual type produce work at a cost almost negligible compared with the economies effected by use of tablets.

Beyond the range of ordinary tableting machines, percussion presses or hydraulic presses may be used for the production of large tablets. Either type of press is naturally slow as compared with the smaller machines first mentioned but may still be economically desirable for special tablets. If, in spite of size, there is no particular need of a single large tablet, molds may be loaded with several of smaller size to avoid these special tablet-

ing devices. This is not always possible, owing to special shapes.

Pressures of 4000 to 8000 lb. per square inch on the material are used to form tablets. The less dense products formed at the lower pressure are satisfactory, provided they do not require much handling and have no sharp projections which would otherwise be broken off. Tablets formed under higher pressures are more durable and better suited to special shapes. In either

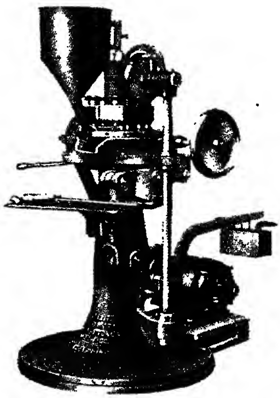

FIG. 73.—Rotary tableting machine. A multiple of punches permits a production of many hundreds of tablets per minute. (*F. J. Stokes Co.*)

case, the strength of the tablet is sufficient to sustain the full molding pressure without crushing, provided it is roughly formed to the shape of the dies.

Ordinarily each size and shape of tablet requires new tableting punches to produce. A disk is one form which permits use of the same punches for any given diameter, the volume being regulated by the adjustment of the machine and affecting the thickness of the tablet only. This probably accounts for the wide use of this form of tablet, even where it may not be the exact shape desired. Of late years there has been a growing use of spherical

preforms. Such a form of tablet is not only the most durable for handling purposes, but may successfully be fed from a hopper. If full automatic molding presses are to be a reality, they will almost certainly be based on the use of spherical tablets for automatic gravity feed.

Finishing Machines.

Perhaps the most important finishing operation consists of removing the fin left on molded articles. While this may be done by use of a soft grinding wheel in a speed lathe, it may better be considered bench work. Here a small polishing spindle with proper wheel is quite satisfactory, while the location is better for work requiring hand-scraping. If the surface finish of the piece is of no importance, the work may sometimes be tumbled, but this cannot be recommended as a regular method of burring. Ordinarily the finish of the mold is depended upon for the surface finish of the piece, and subsequent polishing operations are an unnecessary expense.

Most plastics are adaptable to the usual machining operations and may be sawed, turned, drilled, and threaded. The softer plastics may be handled by wood-working equipment and methods. Thermosetting plastics may require metal-working tools. Cutting tools may be ground to accommodate the material in each case, and for thermosetting plastics, special tungsten-carbide drills are available, ground to suit the material and more durable than the usual carbon-steel drills.

Individual inserts may be "staked in" by means of small, foot-operated riveting machines. Where several inserts are to be set at a single operation, special machines may be developed for the particular purpose. Such machines not only "stake in" the inserts but also automatically place the inserts previous to setting them, thus eliminating much hand labor.

In regard to color, some plastics may require finishing to obtain a shaded or a multiple-color effect. The piece is usually picked up with tongs which fit the surface of the object, where no color is wanted. The color is applied by a compressed-air spray brush. A separate spraying is required for each color, the "masking" effect of the holder or tongs being changed each time to suit. While solid color effects can, of course, be obtained by dipping, it is more logical and in the interest of a better product to include the coloring in the stock itself whenever this may be done.

Preheating Equipment.

Considerable time may be saved in the molding of plastics when the stock may be preheated. The usual method of preheating consists of placing the stock on the surface of a steam table. This may be conveniently made up of an ordinary steam plate set in an insulating material such as asbestos cement and mounted on a pipe stand at a convenient working height from the floor.

Softening at a low temperature, and being practically nonhygroscopic, pyroxylin can be preheated in a hot-water bath. This method is occasionally used in the preheating of such material when it is blanked out of solid stock, while in the particular molding operation known as "drawing," the sheet stock used is always softened in this way.

Tableted material is not preheated in the sense of being made plastic previous to molding but may be carried at a temperature considerably higher than that of the room. The permissible temperature in any case depends upon the plastic and upon the rate at which it is being used. A long warming or preheating period may have a deleterious effect on the material. Tablets may be more successfully warmed in a small oven than on a steam table. Such ovens, with temperature controls,

are available for either gas or electric operation. Steam-heated ovens are usually made up for the purpose, where it is more desirable to use this heating medium.

Hobbing Presses.

Molding plants producing their own molds often find it advisable to install hobbing equipment in addition to the usual machine tools required for mold manufacture. Aside from the convenience of thus having complete control of the mold construction, hobbing equipment of the most suitable size may prove to be an economy where much of this work is required.

The essentials of a good hobbing press are rigidity of frame or rods and a minimum of deflection in the platens, together with a ram sufficiently long to be well guided by the cylinder. Presses designed for other purposes and converted to this use generally fall short on one or more requirements but may occasionally be altered satisfactorily. Large platen presses are usually not suited to the concentration of loading or for alteration.

Hobbing presses are available in a number of sizes from 100 to 5000 tons capacity. For a single installation the very small sizes are convenient but too limited to handle the bulk of ordinary die work. In the other extreme, the large presses represent too great an investment to be left idle, and unless unusual conditions exist they are greatly out of proportion to average requirements. Where a single press is to be installed, one of 600 to 800 tons may be recommended as being a most useful size.

Hobbing-press units ordinarily include the press, hardened-steel anvils, hydraulic gage, operating valve, and a high- and low-pressure pump. The press operates directly from the pump through the "stop, check, and release" valve, no accumulator being used. The pump should be of either three- or six-plunger type to prevent

pulsations affecting the work, and while a high-pressure pump will produce satisfactory work, the high- and low-pressure combination permits faster operation in approaching the work. Desirable accessories include a depth gage or an offset mirror to show depth of hobbing without having to look directly at the work and, for large presses, an elevating table to facilitate handling of heavy chase rings. The chase rings themselves are

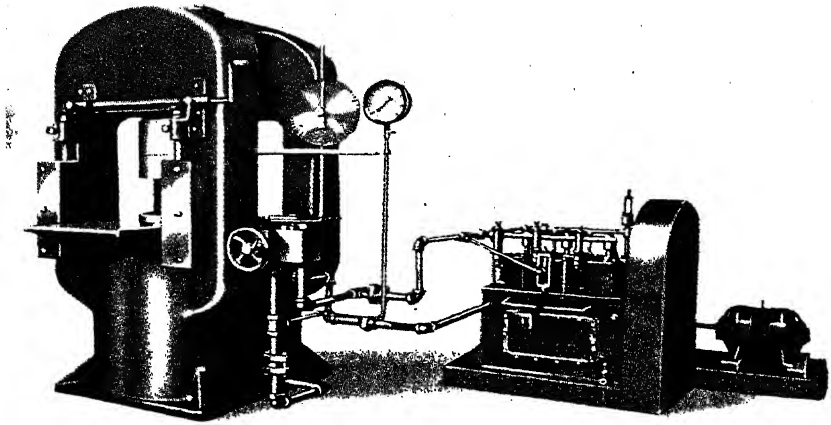

Fig. 74.—Hobbing unit with six-plunger pump, depth gage, elevating table, and hardened steel anvils.

usually necessary accessories but are ordinarily not furnished by the press builder.

As hobs are expensive and easily spoiled—and the hobbing process is a very special one—it is not advisable to entrust the work to unskilled hands. Since experienced operators are few, installation of hobbing equipment usually requires the training of one or more operators from the ranks of tool makers or machinists.

Steam Boilers.

It has occasionally happened that plants attempting to create a molding department as an adjunct to their

regular business overlook the steam equipment in their estimates of expenditures. This oversight is most likely to occur in plants ordinarily using no process steam but having a generous heating-boiler capacity which is expected to be used.

Plastics such as shellac or pyroxylin, having a low and variable molding temperature, may be sufficiently softened by steam from a heating system to be shaped, but the molding pressures required may be as much as 300 per cent of normal pressure. Thermosetting plastics requiring a higher and definite temperature cannot be handled with such low-pressure steam.

If a 250° F. molding temperature is desired at the mold, it may be assumed that there will be sufficient radiation losses to require somewhat more than this at the boiler. The usual allowance for this is 15° to 20°, requiring in this case about 270° boiler-steam temperature. The boiler pressure for this condition would be 25 lb. gage. If the steam source is far removed from the molding department, a 30- or 35-lb. boiler may be selected.

For molding temperatures of 350° F., such as are required for thermosetting plastics, a boiler-steam temperature of 365° F. will require a boiler of 150 lb. gage. For remote location a 175-lb. boiler will be necessary and would be considered a better installation in either case, as it permits the use of slightly higher-temperature steam where such may reduce the molding cycle without harm to the plastic.

In regard to a low-pressure boiler superheating to gain the desired temperature, it may be said that while this is a possibility, it is not advisable, since the heating characteristics of superheated steam are not desirable.

PART IV

THE MOLDING PLANT

CHAPTER X

PLANT EQUIPMENT

Selection of Equipment.

In the selection of all equipment the two separate items of type and size must be determined from the nature and quantity of work to be done.

Presses.—In regard to molding presses, the nature of the work to be considered is the size of the molded piece in its relation to the molding cycle, as well as the relative delays in operation of complicated molds for the production of intricate shapes. Fortunately, the bulk of molded goods is of a size and simplicity which may be turned out on a relatively short molding cycle permitting the investment in high-grade presses most suitable to this work. These are either semiautomatic or tilting-head presses, depending upon the particular requirements.

The first exception to this may be found in the production of very large pieces, even though these pieces may be relatively simple. In such a case, the curing time may be so great as to make it economically undesirable to carry out the molding process in a relatively expensive press making only a few strokes per hour. Such work may be most economically done in a hand-molding unit, where the mold weight is not excessive or otherwise in a simple and inexpensive style of semiautomatic press. The production is no factor in determining the type in such a case.

A second exception to the usual choice may be occasioned by an intricate shape of piece requiring a mold

containing loose pieces, or other features requiring an unusual amount of manual attention. Again, the molding cycle is prolonged, but since the delay in this case is occasioned by the mold, rather than by the plastic, there is some opportunity for improvement through the use of special operating devices which may permit the work to be handled in a semiautomatic press. Where such improvement is possible, the press type will be determined not only by the nature of the work but also by the production, since, if special devices are required, the expense may be justified only by large production.

If the nature of the work is such that it may be equally well produced in hand molds as in semiautomatic molds, the only excuse for the former may be an unusually small production requirement. While the operating costs may be higher, this may be offset by the difference in mold cost for the hand equipment. Novelty goods depending upon styles or quickly changing demands which make investment in expensive molds too great a risk may be handled in this way with hand-molding equipment. The elimination of set-up charges in the case of hand molds is especially advantageous, not only where small production is required, but even more when the production is to be intermittent.

As previously mentioned, the majority of molding problems, perhaps 90 per cent, may be most effectively handled by means of semiautomatic or tilting-head presses. The semiautomatic press is the backbone of the industry, while the tilting-head press of modern design has all of the semiautomatic's features and the tilting-head feature in addition. While the choice between these two may to some degree be a matter of personal taste and previous experience, the tilting-head press is distinctly advantageous for certain kinds of work, and for inspection of dies in all cases. Where initial investment is a major consideration, a very few

tilting-head presses for special work may suffice for the entire plant.

While the foregoing applies to the general competitive molding plant, the equipment needs may be entirely different in the case of a molding department operating for, and subsidiary to, an industrial plant. Here, continued production of standardized parts may even justify the development of special equipment which, for general use, would be of little value.

With the bulk of the press equipment made up of semiautomatic presses, the remainder may be largely hand-molding presses, with the addition of more special equipment as needed. The hand-molding machines will take care of the occasional small production jobs, or long-cure moldings. The need for special machines can seldom be foreseen and may best be added as required. This includes angle and injection presses.

With the type of press equipment determined, the next consideration is size of units, which is determined largely by the production requirements. In general, the larger the production, the larger the mold and press, provided the loading time may be kept to a minimum with the single large mold. After computation of the total number of dies required for a required production, it is frequently found that owing to special loading operations a single large mold will not give so good production as two of half the size. A single operator with two presses may be more advantageously employed with two alternating molding cycles than with a single large press which may require a delay in loading.

As regards size of presses commonly used, it is interesting to observe that, although these sizes have never been standardized, the 75-ton press has been installed more than any other in the past, and that the present tendency is toward larger sizes. The 100-, 125-, 150-, and 200-ton semiautomatics have demonstrated their

advantages and are being installed for large production work. They are available as standard equipment up to 400 tons and may be obtained specially in still larger sizes. Tilting-head presses likewise have been largely of 75-tons capacity in the past but are being installed in larger sizes such as 125 and 150 tons. Presses of this type have been designed for 600 and 1200 tons, but to date, none of these large machines have been installed. Hand-molding presses have been, and probably will remain, chiefly of 75 tons capacity. Such a press fitted with 16- by 16-in. platens offers sufficient tonnage for the maximum size of mold which may be conveniently handled manually. These presses are frequently operated by hand pumps, affording variable tonnage to suit various sizes of molds, not easily accommodated where presses are operated from a main high-pressure line. Angle presses are used in a great range of sizes from 10 to 400 tons, and are no more general in size than in type, usually being installed to suit some special requirement.

Since it is frequently desirable to have molds interchangeable, it is advisable to have several presses exactly alike in type and size. In the small installation, this confines presses to perhaps the 75- and 150-ton sizes, while the larger plant may advantageously use all of the common sizes from 75 tons upward.

Pumps.—In selecting a main-supply pump, the price generally controls the type. The characteristics of a triplex pump are more desirable than of either the two- or four-plunger pumps occasionally installed, but this is not a consideration of great importance in a molding installation. The commonest form of drive for these pumps is by motor, through reduction gears.

Pump capacity may be computed with fair accuracy from the engineering standpoint but is usually affected by economic considerations. Essentially, the pump

capacity is based on the combined requirements of the individual machines. This may be determined from the water displacement of each machine, assuming a working stroke of 6 to 8 in., depending upon the depth of mold from front to back. In computing the displacement, it is important to observe that differential or opposed cylinders may be properly charged with their net consumption only, since the smaller is usually under pressure at all times and does not run water to waste. Similarly, the maximum stroke of the main ram may be used in rare cases, but the average working stroke obtained by proper thickness of molds or positive return stopping of ram provides the best economy in use of water. The displacement per cycle of each machine being determined, the capacity in gallons per minute may be estimated from a knowledge of the average molding cycle for the particular plastic to be molded. While this cycle is, of course, variable, even with a single plastic, it may be approximated closely enough by the equipment or material manufacturer, when previous personal experience is lacking. In theory at least, the capacity of the pump, in gallons per minute determined from the foregoing, is sufficient to serve the entire plant while working continuously. Since this last is a condition seldom realized in practice, the capacity as computed provides some excess over usual operating requirements. Actually, it is customary to install 50 per cent more capacity than theoretically required. This excess is found desirable both to provide for future expansion and to operate an accumulator properly.

Accumulator.—The type of accumulator selected may depend to some extent upon its intended location. Accumulators loaded with fixed weights are generally too heavy to be supported by the ordinary industrial floor without special bracing or support. Such equipment may best be located on a foundation or basement

floor. The air-weighted or hydropneumatic accumulators introduced within the past few years are sufficiently light to be mounted on the same floor as the press equipment. Fixed-weight accumulators are made in two styles. In the one case, the barrel is fixed and the ram is movable. In the second style, the ram is fixed and the barrel is movable. First cost and installation are practically the same, but the first style is generally preferred to the second for reasons of maintenance.

In determining the capacity of the accumulator, it may appear that, since the pump is large enough to continuously operate all of the equipment, the accumulator might be either dispensed with entirely or be of a diminutive size. The first assumption is incorrect, owing to the large volume of water which may be required at any one time by several presses operated simultaneously, and which could not be furnished at the required rate by the pump alone. The second assumption is likewise incorrect and in addition to the insufficient capacity is the very real danger to the piping from the shock of suddenly stopping the small, rapidly dropping accumulator. Obviously, a certain size is required for satisfactory operation, while any excess capacity improves the installation as regards piping and future expansion. Beyond establishing the minimum capacity based on the press requirements, independent of the pump, the problem is one of economics rather than of engineering.

To establish the minimum size of accumulator, a study of the cycles of the individual machines is required. This requires average-time values to be assigned to each press, based on the general run of work to be done in each machine. From these data may be determined the coincidence of the various separate cycles, over any time period, together with the water requirements at that time. It may be well to observe that two or more

presses attended by a single operator preclude the possibility of simultaneous operation and are not to be considered as independently operated units. The accumulator capacity as determined above is altered to suit conditions depending upon the number of presses concerned. Since the probability of simultaneous operation is a function of the inversed square of the number of presses, the capacity of the accumulator becomes decreasingly smaller in relation to the number of presses, although increasing in actual size.

The final determination is based upon experience and upon the particular factors in the individual installation. Obviously, for very few presses the accumulator may well equal the combined capacity, especially when further expansion is considered. On the other hand, in the case of many presses the probability of simultaneous operation is not only very small, but the consequences aside from inconvenience and delay are not serious in case the accumulator has not the combined capacity of these presses. Again, since accumulators cannot conveniently be made to operate together, it is advisable to have adequate capacity in the one unit for further addition of equipment.

In practice it is customary to select an accumulator of 35 to 50 per cent of the capacity of the independent presses when the number of presses is ten to twenty-five. For a smaller number of presses the relative accumulator capacity increases rapidly with a decrease in presses, while for a larger number the assumption of 25 per cent is generally satisfactory.

Tableting Machines.—In selecting tableting machines, it may be assumed that 90 per cent of the molds used are suitable to loading with tablets. On this basis the number of tablets per minute, of any given size, may be determined for the entire installation. While these machines can produce tablets over a large range of

sizes, it is advisable to have machines of various sizes where several units are needed for the total requirement.

Finishing Equipment.—Finishing machines consisting of small drill presses, buffing spindles, riveting machines, tumbling barrels—simple, inexpensive equipment, for which the exact needs cannot be foreseen—may best be selected and installed, as occasion demands. Such equipment varies not only with a difference in plastics but even with the various products of the same material.

Boilers.—In selecting the steam equipment, the boiler pressure will be determined by the temperature desired at the mold, as mentioned previously. The capacity of the boiler will depend upon a number of factors such as continuous or intermittent heating of molds, size of molds, amount of piping, and insulation. Unfortunately, the items which permit of satisfactory computation are those of least importance, while the mold does not lend itself readily to advance calculation of steam consumption. The best test data on steam consumption of molds show 1.3 lb. steam required per minute for continuous heating of a 14 by 31-in. mold. The total thickness of the mold was 6 in., and the mold was operated in a 150-ton press, with a steam pressure of 150 lb. gage. From these and other data it may be concluded that for such conditions of continuous heating at 350° F., 1 lb. of steam per minute may be allowed for a 75-ton press, 1¼ lb. for a 100- to 125-ton press, 1½ lb. for a 150-ton press, 1¾ lb. for a 200-ton press. Assuming a 15-lb. pressure drop from boiler to press, 1 lb. of steam per minute at the press requires 2 boiler horse power. This figure, while not exact, is convenient and safe for estimating the required capacity of boiler for a similar installation. Where alternate heating and chilling are required, the steam consumption may be as much as 600 per cent of that required for continuous heating.

Plant Layout.

Floor Loads.—Molding equipment, with the exception of relatively few items, may be satisfactorily carried by any industrial floor suitable for machine tools. Pumps and accumulators are most conveniently placed in the boiler room, although this is not a necessity from the floor-load considerations if a hydropneumatic accumulator is used. An especially heavy machine, such as a large hobbing press, may require some special floor bracing but otherwise may be arranged without this special consideration.

Press Arrangement.—Overhead lighting, from monitor or saw-tooth roof construction allows the greatest freedom in the placing of equipment, but such installations are the exception rather than the rule. In the usual case, the molding room is relatively long and narrow and carries windows in the long walls. For this condition the presses are best arranged in parallel rows perpendicular to the window walls, as shown in Fig. 75. Economy in floor space is effected by placing alternate rows back to back, grouping the piping in a common aisle and providing a wider working aisle for the operators. Where hand trucks are used for the supplying of material and removal of molded goods, the working aisle should be at least 6 ft. wide. A main central aisle running the length of the room, is generally included in this press arrangement and in not being otherwise obstructed should provide clearance for two hand trucks to pass.

For the convenience of the operator additional equipment may be required, such as storage space for material and for molded work. With working aisles of sufficient width, this may be accomplished by continuous or separate benches in back of the operators. Such an arrangement provides ample room for tools, oven for preheating

tablets, and for other accessories. Individual tables may be used in place of the continuous bench when the molding process may require grouping of equipment around the operator, as in hand molding. In this case

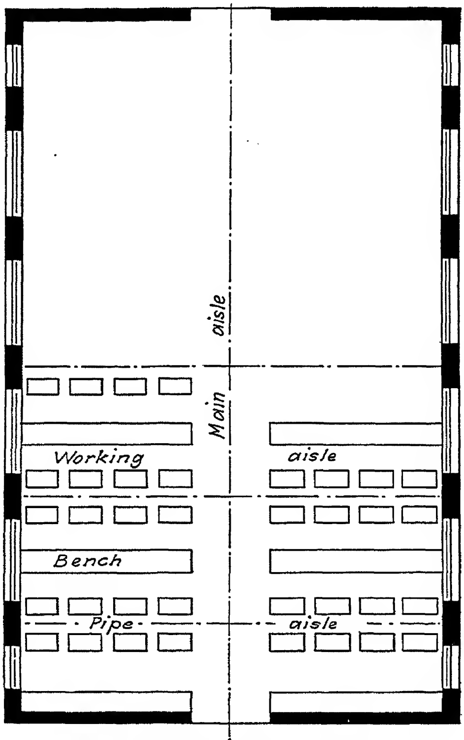

FIG. 75.—Preferred press layout.

the operator has the hot-press in front of him and the chilling press at his left. The table in back of him is used in unloading the hand molds which are then preheated on a steam table at his right. The arbor presses sometimes used for stripping hand molds may most conveniently be placed to the left, between the chilling press and the table.

Tableting.—Since tableting ordinarily causes considerable dust, this operation may well be performed in a room set aside for that purpose. In addition to this, if various colors are being tableted in separate machines at one time, it is advisable to have each tableting machine in its own dust-proof compartment provided with an exhaust system.

Finishing Equipment.—Finishing equipment placed in a room by itself may be well arranged in having handwork performed at benches running along the walls, leaving the central space for mechanical equipment. Inspection and packing may be done in the same room when space is limited.

Proximity of successive departments tends toward the greatest efficiency in producing the finished work from the raw material. However, since the plant may occupy several floors, or parts of several floors, no general layout can be evolved to suit all conditions. The particular layout should be based primarily on the progressive handling of the material in adjoining departments, unless unusually poor facilities do not permit. Aside from the actual floor space required, the inclusion of a tool-making department for the production of molds need not interfere with the proper layout of molding equipment, since mold making is entirely unrelated to the primary process in its location.

Installation.

Piping.—In the installation of press equipment the matter of hydraulic piping is a major consideration. The smaller sizes of piping may be determined from the individual presses, and for 3000-lb. lines is ordinarily ¾ to 1¼ in. double extra heavy pipe. Allowing for a 50-per cent friction loss in the line, which is not unusual with such high pressures, this permits a closing speed of 1 in. per second in most cases, requiring 6 to 10 sec. to

close the mold, depending upon its size and initial opening required. Unless quicker curing plastics are introduced, the agitation for higher press speeds is not well founded, as the closing time is at present a nominal part of the cycle, not justifying the added expense of larger piping. To obtain corresponding speeds with the lower line pressures sometimes used, such as 1800 and 2000 lb. per square inch, larger pipe must be installed. Since this is of the same grade as that employed for the higher pressures, the piping expense is relatively higher in the installation of such low-pressure systems.

The high-pressure mains supplying the individual distributing lines to the presses should in theory have a cross-sectional area equal to the combined areas of the pipes served. Such an installation would provide for the emergency of all presses acting simultaneously and would require a continually decreasing size of main as successive branches are taken off. While this is desirable, the chances of such a demand are ordinarily too remote to justify the expense of such an arrangement. The same compromise in capacity may be made here, as in the accumulator. That is, the supply main need be no larger in proportion to the total lines served than the accumulator is, relative to the combined capacity of the presses. This size of main should be carried forward from the point of connection with the accumulator and may be reduced once or twice after sufficient branches have been taken off. Since the feed line from the pump bears no particular relation to the size of the supply main, its size may be established by the outlet tapping of the pump, and it may be tied into the high pressure system at the most convenient point.

Valves.—Hydraulic operating valves are most conveniently located at the right of the press. When additional valves are required for the operation of special

devices, it is sometimes advantageous to locate such valves out of reach from the first. This avoids the possibility of simultaneous operation and consequent injury to the mold, where valves are to be operated in sequence.

As ordinarily installed, an inverted-ram press contains an element of danger of injury to operator and mold, in case of failure of the line pressure when the mold is open. This danger may be eliminated by the installation of special safety valves, now available, in the pull-back line.

Air Lines.—For the convenience of the operator in blowing out and cleaning dies it is desirable to have compressed air available at each molding press. This is generally distributed from a central single-stage compressor, furnishing air at perhaps 75 lb. pressure. The lines leading to individual presses may conveniently be ¼-in. pipe, terminating with a stop valve, from which point, a flexible hose equipped with a nozzle valve may be used to reach the dies.

Lighting.—Owing to the nature of the equipment, general overhead lighting is of little service to the press operator. Where artificial lighting is required, this can be most effectively installed as individual drop lights which permit of manipulation to suit the particular requirements at each press.

Timing Device.—For plastics requiring a definite time for cure, some sort of timing device is advisable for each operator. Electrically operated clocks have proved to be very convenient in this capacity, especially those operating a light when the cure is completed. The timing may be varied at will to suit various cycles, and since a manual reset is required each time, such a device commands the proper attention which may be lacking with a continuously operating clock.

Operation.

Material Supply.—In the operation of the plant, an important item is the supplying of material to avoid interruption of production. The molding material, generally in tablet form, is usually distributed to the operators by means of hand trucks. Standardized

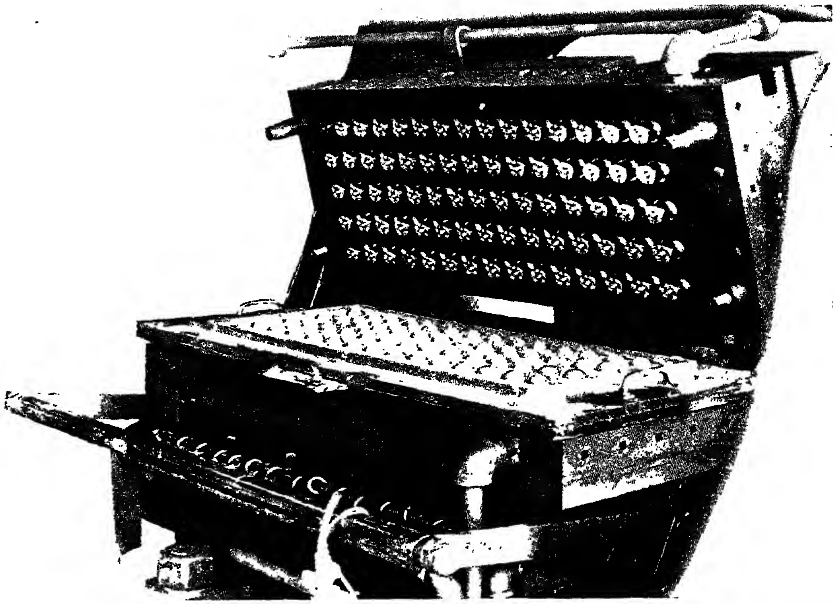

FIG. 76.—Loading board with spherical preforms, or "pills," ready to charge mold. (*Westinghouse Lamp Co.*)

metal pans, or boxes, carrying 30 to 50 lb. of material each, offer a convenient means of handling the supply. For the relatively few cases requiring loading with loose-bulk material, the material may be supplied to the operator in properly weighed charges when the cycle does not allow him time to weigh out his own material. Paper cups or cartons are inexpensive and effective containers for such materials in transit. A material

such as shellac, which permits of preheating to a great degree of plasticity, may be distributed in slabs, which, after softening, may be cut up by the operator as required.

The Molding Cycle.—In the cycle of molding, the loading of the mold is of more importance than formerly, since quicker curing plastics permit shorter cycles in which the loading time may represent a substantial part of the entire cycle. To reduce this to a minimum, loading or dropping boards should be used with all multiple-cavity molds using preformed material (Fig. 76). These double-bottom trays space the preforms above the die cavities, so that when the sliding bottom is moved, the tablets drop through the board and into the respective dies. Such boards, of course, must be made to suit the spacing and tablets for each different mold, but their cost is negligible in comparison with the savings effected by simultaneous loading of all dies. The boards are reloaded each time during the curing of the material already in the mold.

Compressed air may be used between cycles for blowing out loose flash which may drop in the dies. Where excess material cannot be dislodged by this simple means, scraping or rubbing may be required. Scrapers for this purpose should be of very soft brass or copper, to avoid injuring the surface of the die. A soft copper brush, driven through a flexible shaft, is effective for such cleaning.

In unloading the mold it is advantageous to have automatically ejected work drop from the top die, so that it may be received in a tray. Where this is not feasible, it is sometimes possible when the shape of molded parts permits, to lift all parts simultaneously from the lower dies, by use of a comb (Fig. 77).

Removal of Work.—The removal of molded work frequently employs the same pans and hand trucks as used

in distributing material. If the presses are producing a variety of work, this is probably as expedient as any other method, unless a finishing room below permits use of chutes from individual presses. Belt conveyors are used for the removal of molded parts when the work is uniform and not requiring separation, as is the case

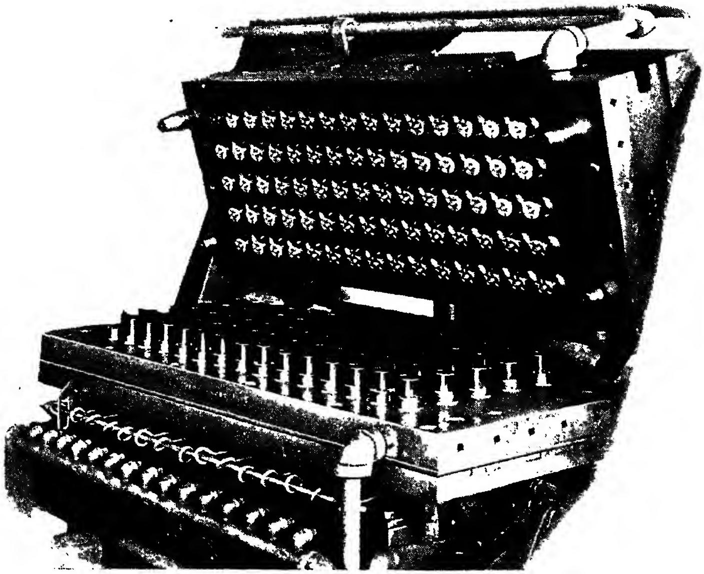

FIG. 77.—Elevation of work from lower dies to permit removal by means of comb. (*Westinghouse Lamp Co.*)

with a varied product (Frontispiece). Such belts may even be arranged to handle more than a single product but are not suitable for a great many, handled simultaneously.

Finishing.—The bulk of molded products may be finished by tumbling. In many cases the parts alone are placed in the tumbling barrel, a relatively short tumbling being required to remove the usual light fin. Occasionally, wooden blocks or leather-findings tumbled

with the parts improve the action. Light drill presses provide for drilling and tapping parts requiring such operations. This work may be best performed at benches where the operators may be seated. Setting inserts by "staking-in" may be likewise made a bench operation. Such finishing operations do not require adult male help and can generally be accomplished at lower cost than the same result obtained directly from the molding operation. Special machines, for the simultaneous "staking-in" of several inserts in a single piece are occasionally developed for particular jobs, but owing to the cost and limitations of such equipment, such practice can be followed only in case of unusually large production.

Inspection.—Inspection of work varies to suit the nature of the product, from a casual inspection of novelty goods, to precise gaging of mechanical parts. In the latter case especially it is a great convenience to have the individual dies of a multiple-cavity mold distinctively marked, so that a faulty impression may be easily determined from inspection of the work. Inspection of work may in rare cases include tests for strength, insulation, absorption, and other characteristic properties of the material. Ordinarily such tests are performed on standardized test specimens of the material, previous to its adoption. Since the properties of the more common materials are reliable enough for ordinary use, such testing may usually be dispensed with, except in developing new mixtures for some special purpose, in which case the plastics manufacturer generally performs this work.

Packing.—Packing is as variable in quality as inspection, depending entirely upon the nature of the product. Individual novelty articles may warrant careful wrapping and perhaps special cartons where such goods may be disposed of through the mails. In the majority of

cases several articles may be included in one container with a nominal amount of protection, while in the extreme, small parts may be packed in gross lots with no separation of individual parts.

Maintenance.

In regard to maintenance, the press equipment contains a few elements which require attention, namely, packings, valves, steam connections, and alignment of platens.

Packings.—Where no record of performance is kept, delays caused by replacement of packings may be a source of great annoyance and expense, especially with certain styles of presses, in which inherently poor design makes replacement difficult. A simple expedient is to adopt a particular make and quality of packing, keeping a record of performance for a time until its life in service has been determined. After this, replacements may be made during regular shut-downs, after packings have served a normal life, rather than wearing them until they blow out in service. Oak-tanned packings are generally satisfactory when sufficiently insulated from heat. Where this is impossible, chrome-tanned leather will ordinarily fill the requirements. Occasionally, composition packings of canvas and rubber are used and show good wearing qualities.

Valves.—Hydraulic valves require a certain amount of regrinding to eliminate leakage caused by wire drawing. This being a gradual development, such maintenance may be scheduled to suit normal shut-downs. Valve leakage may be detected by the creeping of the ram from its retracted position when both inlet and outlet are presumably shut. Such ram movement indicates a leaky inlet valve. If the mold is closed under pressure and both inlet and outlet are closed, the ram will creep toward its retracted position in case the outlet leaks

appreciably. A minute leak may not allow creep of the ram while still failing to hold the initial pressure in the cylinder and may not be detected except by means of a pressure gage between valve and press. The operation of the valves has a great deal of effect on the amount of wire drawing. If operators are permitted to throttle habitually in opening valves, a great deal of regrinding will be required to restore these valves, regardless of the material used for spindle or seat in such valves.

Steam Joints.—The steam connections to the press require periodic attention in tightening, repacking, or replacement. The long stuffing box possible when slip joints are used probably requires the minimum of attention for movable steam joints. Ordinary swing joints perform satisfactorily when kept continually heated but are a source of annoyance for chilling and heating. Patent swing joints employing composition packing disks are an improvement over the older type for severe service. Flexible copper tubing used in coils requires very little attention and has as its chief objection only its unsightly appearance. Patent fittings are available, making connections quite simple and effective.

Platen Alignment.—Since it is important to avoid localized pressure on the mold, it is essential that the surfaces be parallel on closure. Presses of the rod type may require an occasional realignment of platens, owing to unequal stretching of rods or a loosening of the nuts. Such adjustments are infrequent with a well-designed press, however, and can usually be confined to the period of initial set-up of the mold, unless this is continually in service for a very long time.

Mold Maintenance.—Maintenance of a properly constructed mold is an item of small expense, and is ordinarily limited to a repolishing of dies required by some unusual conditions of operation, such as unexpected chemical reaction of the plastic or extraordinary abrasive

action of the filler. A good plastic will maintain the original polish of the dies, with the help of an occasional cleaning in service by the press operator. Molds manually handled require considerably more attention than semiautomatic molds, owing to the battering and abuse they may receive. An item of importance, usually neglected, is the condition of the heat-transmitting surfaces of such molds. These should preferably be ground surfaces and should be maintained in smooth condition for best efficiency. Molds out of service or in storage should be thoroughly greased to preserve the die surface, while in use no lubricant should be required.

Hydraulic System.—The accumulator and pump equipment require no special attention beyond occasional repacking and lubrication. In case of a motor-driven pump, it may be found that an ordinary motor will not stand the repeated full-load starting and will eventually burn out. The minimum size of motor satisfactory for this service must be specially wound for a heavy starting torque.

Conclusion.

In conclusion it may be said that molded plastics have found application in so many fields within the past few years, with increasing demands of precision in fitting of parts, surface finish, coloring, and difficulty of molding, that the slow-moving and relatively crude equipment of the early years of the industry is almost a thing of the past. Some of the early plastics are still being handled in antiquated equipment but at the expense of either precision, or production. To compete on a favorable basis, it may be expected that this older equipment will be replaced with more modern presses and molds described in the foregoing chapters, developed since the introduction of synthetic-resin plastics. While the expense of such equipment is deplored by many at first

glance, it may readily be shown that quality and quantity of output make such equipment a sound investment when used with modern molding methods. It is sometimes suggested, by the visionary, that the entire hydraulic equipment of a molding plant might be dispensed with if a suitable plastic could be developed. While this is doubtless true, there is no indication that such a plastic, if found, would otherwise have properties sufficiently desirable to recommend it for general use. In addition, if the process should thus become one of casting and solidifying a very plastic material, the objections to this would, in all probability, outweigh its supposed advantages.

Thus, while plastics retain the present requirements of heat and pressure for molding, reduction of operating costs can come not through change of method but only in improvement in present methods. In use of high-pressure water, improvement is limited to patented short-stroke presses or to adoption of high- and low-pressure hydraulic systems. In regard to heating requirements, it may be expected that steam consumption will be reduced, from its only point of attack—radiation losses. To date no serious attempt has been made to reduce radiation losses at the mold itself, while piping insulation is in many cases casual and ineffective.

Practically no research has been done in the field of hobbing, this process of forming dies serving a very limited field and not being generally known. The advantages of this process are so obvious for precise die work that its general adoption is practically a necessity in such cases, and a matter of economy in most cases. It may be expected that development of the hobbing process through its wider use will lead to further economies in mold-building.

As regards the future of the plastic-molding industry, it is apparent that in spite of its phenomenal growth of

the past twenty years it is far short of its probable proportions. As witness to this it will be observed that to date the bulk of molded products has been chiefly novelty, decorative, or mechanical parts of relatively small size. The small beginning in the field of furniture and building materials opens up an entirely new line of application of molded products of larger size than is common at the present time. Thus, while the displacement of less desirable materials has been almost entirely confined to articles of small size, the trend has been toward molded parts of increasing size, which in turn has opened up new possibilities of application. In this new field of larger molded products speculation is idle as to the displacement of present materials, since the possibilities are manifold and not defined. With no apparent resistance on the part of the buying public, the responsibility for the development of this field falls to the plastic-molding manufacturer.

APPENDIX

Table. IX.—Plastic Products and Producers[1]

[DESCRIPTIVE CODE AND ABBREVIATIONS]

B	Inorganic	PF	Phenol formaldehyde
C	Casein	Px	Pyroxylin
CA	Cellulose acetate	SG	Safety glass
D	Resin used as ingredient	UF	Urea formaldehyde
F	Fabricator's trade name	V	Viscose
GP	Glycerol phthalic anhydride	W	Wood fiber
O	Obsolete	X	Miscellaneous
P	Packaging material	?	Nature not known
f	Forms, sheets, rods, etc.	s	Soluble for varnish, impregnation, etc.
l	Laminated board, etc.	t	Turnery-type (not moldable) articles made by casting and machining
m	Molding compound		

Blücher: "Plastische Massen" by Hans Blücher, Salomon Hirzel, Leipzig, 1924.
Brit. Plastics: British Plastics and Moulded Products Trader; London.
CGP: Le Caoutchouc et la Gutta-Percha, 49, rue des Vinaigriers, Paris.
Cellulose: Cellulose Publishing Co., 114 E. 32d St., New York.
Gummi-Ztg.: Gummi-Zeitung, Krausenstr. 35, Berlin.
GZB: Warennamen-Verzeichnis, Beilage zur Gummi-Ztg.
Hemming: "Plastics and Molded Electrical Insulation," by Emile Hemming, Chemical Catalog Co., New York, 1923.
Kausch: "Handbuch der künstlichen plastischen Massen," by O. Kausch, J. F. Lehmann, Munich, 1931.
Kunstst: Kunststoffe, J. F. Lehmann, Munich.
Nitrocellulose: Verlag Pansegrau, Berlin—Wilmersdorf.
Plastics: Plastics and Molded Products, 114 E. 32d St., New York.
Rev. Gén. Mat. Plast.: Revue générale des matières plastiques, 29, rue Turgot, Paris.
Transparentfolien: by M. Halama, Bodenbender, Berlin, 1932.

Name	Description	Manufacturer or reference
Abalak	PF, s	Kunstharzfabrik Dr. Fritz Pollak, Vienna, Austria.
Abalyn	D	Hercules Powder Co., Wilmington, Del.
Aceite	Bituminous	American Hard Rubber Co., Akron, Ohio.
Acelloid	CA, m, F	General Plastics Corp., London, SE 13, England.
Acéloid	CA	Cie. Petit-Collin-Oyonnithe, Paris, France.
Acelose	CA	American Cellulose Co., Indianapolis, Ind.

[1] Compiled by Mr. A. F. Randolph, of the du Pont Viscoloid Company, reprinted by courtesy of *Chemical and Metallurgical Engineering*. Corrected to April, 1933. Of the 150 American and 650 foreign names listed, some have passed out of the active field but are here included as a matter of reference.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Acéta	CA	Cie. Petit-Collin-Oyonnithe, Paris, France.
Acetaloid	CA, m	Acetate Products Corp., Ltd., London, England.
Acetex	CA, SG	England, Chem. Trade J., **85**, 396, 1929.
Acetoid	CA	Punfield & Barstow, Ltd., London, England.
Acetol	CA	Société des Usines Chim. Rhone-Poulenc, Paris, France.
Acétophane	CA, P	Société Industrielle de l'Acetophane, Brussels, Belgium.
Acetylon	CA	Dynamit A.G., vorm. Nobel, Hamburg, Germany.
Acidur	Acid-resistant moldings	Cable Mfg. Co., Ltd., England.
Acrolite	X, m, l, phenol glycerin	Continental Diamond Fibre Co., Newark, Del.
Ad-Triplex	O, Px, SG, with lithogr	Triplex Safety Glass Co. of North America, Clifton, N. J.
Aerialite	x	S. Allcock & Co., Ltd., England.
Aerolite	SG	Duplate Corp., Pittsburgh, Pa.
Aevolit	see Haefelyte	
Agalyn	Px, dentures	J. D. Whyte, Co., Pittsburgh, Pa.
Agatine	PF, t, rods	Société Nobel Française, London, England.
Agfa-Viscose	sponge	I. G. Farbenindustrie, Berlin, Germany.
Aico	X, cold-mold	American Insulator Corp., New Freedom, Pa.
Akalit	C	Akalit Kunsthornwerke A.G., Vienna, Austria.
A-K	PF, m, asbestos	CGP, **29**, 15954, 1932.
Aladdinite	C, f	Aladdinite Co. Inc., Orange, N. J.
Alberit	PF, ?, t	Chem. Fab. Dr. Kurt Albert, Wiesbaden, Germany.
Albertol	PF, m, s, t	Röhm & Haas, Philadelphia, Pa.
Albolit	PF, t	Augsburger Kunstharz-Fabrik, Augsburg, Germany.
Alboresin	UF, m	Kontakt-Römmler A.G., Frankfurt a./M., Germany.
Alborid	Px	Kausch.
Alcolite	Px, dentures	Ransom & Randolph Co., Toledo, Ohio.
Aldur	UF, m	Aldur Corp., Brooklyn, N. Y.
Aldydal	PF. ?, molded articles	I. G. Farbenindustrie A.G., Frankfurt a./M., Germany.
Algalith	C	de Charraud, Rueil, France.
Algine	Algin, plastic	Paul Glaess.

Table IX.—Plastic Products and Producers.—(*Continued*)

Name	Description	Manufacturer or reference
Alino	Px, F	R. Strauss & Co., Frankfurt a./M., Germany.
Alkalit	C	Alkalit Kunsthornwerke A.G., Vienna, Austria.
Amalith	PF	Kausch.
Amberdeen	PF	Kausch.
Amberglow	PF, t, luminous	Labs. Industriels d'Asnières, Paris, France.
Amberit	PF	Kausch.
Amberol	D	Resinous Products Co., Philadelphia, Pa.
Ambra	PF, clear solid	Plastics, **4**, 263, 1928.
Ambrasit	PF, t	Chem. Fab. Ambrasit, Vienna, Austria.
Ambroid	X, pressed amber	Blücher, 188.
Ambroin	PF, etc.	Ver. Isolatorenwerke A.G., Vienna, Austria.
Amerith	Px, f	Celluloid Corp., Newark, N. J.
Ameroid	C, f	American Plastics Corp., New York, N. Y.
Amiantine	Copal, plastic	Société Roux, Paris, France.
Amzylolithe	CA	Société Lyonn. de Celluloide., Lyon, France.
Annalith B	Gypsum, plastic	Blücher.
Annealogic	X, insul. mat	Teleg. Const. & Mtnce. Co., London, England.
Apiroid	Px	Kausch.
Ardenite	PF, ?, m	F. G. Stokes, Ltd., Altrincham, England.
Argolit	C	Argo Chem. u. Nahrungsmittel Fabrik., Prerov, Czechoslovakia.
Argonite	Px	Kausch.
Arki	Wall board	Isoleringsfabrik Arki, Stockholm, Sweden.
Aroclors	Chlor. diphenyl resins	Swann Chemical Co., Anniston, Ala.
Artriplex	O, Px, SG, with color plastic	Triplex Safety Glass Co., Clifton, N. J.
Asbestite	B, asbestos	A. Vaucheret, Paris, France.
Askol	PF	Anglo-Scottish Chem. Co.
Astra	F	Spritzgiessereien, Haslinger & Pesse, Vienna, Austria.
Astrinite	Bituminous	General Plastics Corp., London, SE 13, England.
Athrombit	Px, F	F. & M. Lautenschlaeger, Munich, Germany.
Atlas	PF, l	H. Clarke & Co., Manchester, England.
Atlastik	Px, F	Atlas Ago Chem. Fab. A.G., Leipzig, Germany.
Avecolite	PF, l	Willmott Sons & Phillips, Ltd., England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Axolith	C	Société l'Oyonnaxienne, Oyonnax, France.
A Winto	Px, F	Adolf Winter, Ober-Esslingen, Germany.
Bakdura	PF	**Plastics, 6,** 705, 1930.
Bakelaque	PF, l	Attwater & Sons, Preston, England.
Bakelite	PF, m, l, t, s	Bakelite Corp., New York, N. Y.
Balenit	X, shellac base	**Kunstst., 10,** 110, 1920.
Bandalasta	UF, F	Brooke & Adams, Ltd., England.
Basselon	F, ware	C. Basse & Cie., Luedenscheid, Germany.
BCM Brownie	F, ware	Brownie Wireless Co., London, England.
Beacon	UF, F, ware of Beetle powder	
Beatl	UF, F, ware	Beatl Sales, Ltd., England.
Beckacite	synth. resin	A. F. Suter & Co., England. Beck, Koller & Co., Detroit, Mich.
Beck-O-Lac	D	Beck, Koller & Co., Detroit, Mich.
Beckosol	D	Beck, Koller & Co., Detroit, Mich.
Beerit	B, water glass, min. fillers	**Blücher,** 266.
Beetle	UF, m	Beetle Products Co., Ltd., England. Synthetic Plastics Co., New York, N. Y.
Beetleware	UF, F, from Beetle	Beetleware Corp., New York, N. Y.
Belco	?	Nobel Chem. Finishes, Ltd., Slough, England.
Bellaphan	Px, etc.	Kalle & Co. A.G., Wiesbaden-Biebrich, Germany.
Belleroid	rubber base	Barret & Elers, Ltd., London, E 3, England.
Belling-Lee	C, F	Belling & Lee, Ltd., Middlesex, England.
Belplastic	F	Belplastic, Ltd., London W 11, England.
Bennetate	CA	B. A. Parker, London, England.
Bernit	CA	Zelluloidwaren Fabrik, Zollikofen, Switzerland.
Bex	PF, F	British Xylonite Co., Ltd., London, E 4, England.
Bexite	F	British Xylonite Co., Ltd., London, E 4, England.
Bexoid	CA	British Xylonite Co., Ltd., London, E 4, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Bicella	V, cellophane-coated netting	Kalle & Co., Wiesbaden-Biebrich, Germany.
Bikakapseln	V, bottle caps	Kalle & Co., Wiesbaden-Biebrich, Germany.
Bikarton	PF	**Plastics, 6,** 705, 1930.
Billac	F	W. E. Amies & Co., Ltd., Sheffield, England.
Bincolithe	X, m, resorcinol, trioxymethylene	German General Electric Co., Berlin, Germany.
Birmite	UF, F, from Beetle	E. Elliott, Birmingham, England.
Bituba	PF	**Plastics, 6,** 705, 1930.
Bogophane	V, P	Soc. anon. Bogophane, Palermo, Italy.
Bois Cerame	gelatine	**Kausch.**
Bois Durci	albumen	Cie. Générale d'Électricité, Paris, France.
Bonnywave	PF, UF, F	Reynolds Spring Co., Jackson, Mich.
Boschbakelit	PF	**Plastics, 6,** 705, 1930.
Braylite	?	American Insulator Corp., New Freedom, Pa.
Britmac	PF, C, F	C. H. Parsons, Ltd., Birmingham, England.
Britsulite	PF, m	British Insulite, Ltd., Rochdale, England.
Brofo	X, coumarone resin	Brown & Forth, Ltd., London, England.
Brolonkapseln	V, bottle caps	Chem. Fab. Heyden A.G., Dresden-Radebeu, Germany.
Butaceta	F	I. G. Farbenindustrie, Frankfurt a./M., Germany.
Campbellite	PF, l	Campbell Fibre Co., Stanton, Del.
Camphoid	Px	**Kausch.**
Capes Viscose	V, P, closures	du Pont Cellophane Co., Delawanna, N. J.
Capsules de Glutoid	gelatine	**Kausch.**
Carbolite	PF, ?	Soc. Ind. des Matières Plastiques, France.
Carboloid	PF, m	Carboloid Products Corp., New York, N. Y.
Carnalithe	C	Barthélemy.
Carta	PF, impr. paper	Isola-Werke A.G., Düren, Germany.
Cascaphane	Px, F, closures	Cascaloid, Ltd., Leicester, England.
Caseilithe	C	Soc. Ind. du Celluloide, Paris, France.
Casoide	C	**Plastics, 2,** 123, 1926.
Casolith	C	L. M. Mears & Co., London, England.
Cassoid	C	Maison Blanpain, Ezy, France.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Catalin	PF, t, s	American Catalin Corp., New York, N. Y.
Cedra-Glas	coat. netting	Haver & Becker, Oelde, Germany.
Cégéite	synth. resin	Cie. Générale d'Électricité, Paris, France.
Celanese	CA, m	Celanese Corp., New York, N. Y.
Celastic	Px, boxtoe material	Celastic Corp., Arlington, N. J.
Celastoid	CA, f	British Celanese, Ltd., London, England.
Celescot	O, Px, m	Celescot Co., Toledo, Ohio.
Cellabutol	Px, F	I. G. Farbenindustrie, Frankfurt a./M., Germany.
Cellanite	lamin. board	Micanite & Insulators Co., London, E 17, England.
Cellastine	CA, m, f	British Celanese, Ltd., London, England.
Cellemit	CA	Blücher 153.
Cellesta	Px	Verein für Chem. Industrie, Frankfurt a./M., Germany.
Cellglass	V, P	Chem. Fab. Cellglass, Holland.
Cellit	CA, acetyl cell.	Farbenfabriken Fried. Bayer, Leverkusen, Germany.
Cellobase	Px, CA, V, F	Raymond Boisdé, Paris, France.
Cellofoil	P	Cellofoil, Ltd., Manchester, England.
Celloforme	?	Société la Celloforme, Paris, France.
Cello-Metall	clphne with metal foil	Kalle & Co., Wiesbaden-Biebrich, Germany.
Cellomold	CA, inject. mold	F. A. Hughes, Ltd., London, England.
Cellon	CA, f	Deutsche Celluloid Fabrik, Eilenburg, Germany.
Cellophan	V, P	I. G. Farbenindustrie A.G., Frankfurt, Germany. Société la Cellophane, Paris, France.
Cellophane	V, P	du Pont Cellophane Co., Buffalo, N. Y. Canadian Industries, Ltd., Montreal, Canada.
Cellosilber	celluloid with metal coatg.	R. Kiefer, Dresden, Germany.
Cellosite	CA, P	Ettore Rossi, Milano, Italy.
Cellstop	P	Brit. Plastics, **2**, 227, 1930.
Celluclaire	Px, P	
Celluin	CA, f, m	Pavel Rie & Sohn, Prague, Czechoslovakia.
Celluline	Px	Kausch.
Cellulit	C	Société Ind. du Celluloide, Paris, France.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Cellulith	W, sulphite pulp plastic	H. Brunswig. (USP 622,325).
Cellulodine	Px	Kausch.
Celluloid	Px, f	Celluloid Corp., Newark, N. J.
Cellulosine	Px	Cadoret & Degraide.
Cellusine	P	Langheck & Co., London, EC 3, England.
Cellutite	CA	G. Convert & Cie., Paris, France.
Celluvert	C	Soc. Ind. du Celluloide, Paris, France.
Cel-O-Glass	CA coated netting	Acetol Products, Inc., New York, N. Y.
Celoron	PF, m, l	Continental-Diamond Fibre Co., Bridgeport, Pa.
Celotex	W, board from bagasse	Celotex Co., Chicago, Ill.
Celtid	Px, f	Rhein. Gummi u. Cell Fabrik, Mannheim, Germany.
Cerite	Pf, s	Clément & Rivière, Paris, France.
Cervinite	CA	Zelluloidwaren Fabrik, Zollikofen, Switzerland.
Cetaphane	V, P	Transparent Paper, Ltd., Bury, England.
Cetec	X, cold-mold	General Electric Co., Meriden, Conn.
C-E 950	PF, dentures	Coe Laboratories, Inc., Chicago, Ill.
C. F. Board	PF, l	Campbell Fibre Co., Stanton, Del.
Ciba	UF, ?, m	Soc. Chem. Ind., Basel, Switzerland. Ciba Co. Ind., New York, N. Y.
Cilkloid	Px, surgical wrapping	U. S. A.
Cinelin	Px, CA	Cinelin Co., Indianapolis, Ind.
Cinerit	X	Pétrier, Tissot & Raybaud, Switzerland.
Ciro	Px, records	Celluloid Printers, Ltd., England.
Clar-Apel	V, P	duPont Cellophane Co., Inc., New York City.
Clarifoil	CA, P	British Celanese, Ltd., London, England.
Claritone	F	Ashley Wireless Teleph. Co., London, England.
Clarophan	P, gelatine	Continental Gelatine Ind., Michelstadt, Germany.
Claudilithe	C	Plastics, **2**, 396, 1926.
Clémateite	PF	Rev. Gén. Mat. Plast., **8**, 157, 1932.
Clematite	bituminous	Kausch.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Clubman	CA, F	A. W. Kanis, London, England.
Colasta	X, m, sulphonated oil; formaldehyde.	Colasta Co., Inc., Hoosick Falls, N. Y.
Coltrock	PF, cold-mold	Colt's Patent Firearms Mfg. Co., Hartford, Conn.
Coltstone	X, cold-mold	Colt's Patent Firearms Mfg. Co., Hartford, Conn.
Concordia	F, molded articles	Concordia Elec. Safety Lamp Co., Cardiff, Wales, England.
Condensite	PF, m	Bakelite Corp., New York, N. Y.
Coralex	PF	Société Française, Vitry, France.
Cornalithe	C	de Charraud, Rueil, France.
Cornit	horn plastic	Kausch.
Coronal	UF	Société l'Ambrolithe, Paris, France.
Corozite	C	Soc. Anon. Prodotti Corozite, Gorlago, Italy.
Crayonne	CA ?, m	Crayonne, Ltd., Bexley, Kent, England.
Craypax	P	Waxed Bags, Ltd., London, England.
Crepophane	P	Linium Products Synd., Ltd., Nottingham, England.
Cristalux	CA, sheeting	Acetate Products Corp., Ltd., London, England.
Cristalyx	UF	Edgard Israel, France.
Cristore	CA, ? sheeting	Speights, Ltd., England.
Crommoid	F, synth. res. ware	Cromwells, Ltd., Staffordshire, England.
Cromware	F, synth. res. ware	Cromwells, Ltd., Staffordshire, England.
Crystalate	F, molded goods	Crystalate Gramophone Record Co., Kent, England.
Crystalite	UF	Röhm & Haas, Philadelphia, Pa.
Crystallone	F, cut glass imitat.	Paul Schlochoff, Paris, France.
Crystillin	PF, t	Crystillin Products Corp., Brooklyn, N. Y.
Crystur	UF, t	Panplastics Heyden Chem. Co., Garfield, N. J.
Cumar	cumarone base	Barrett Co., New York, N. Y.
Cupren	copper-acetylene	Kausch.
Curvitas	F, CA ?	A. W. Kanis, London, England.
Dako	?, m	Commercial Utilities, Ltd., London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Damarda	PF, s, metal coating	Bakelite, Ltd., London, England.
Daspi	F	Deutsch. Allgem. Spritzgusswerk, Nürnberg, Germany.
Decosan	?	Shanks & Co., Renfrewshire, Scotland.
Deedoid	F	Aberdeen Combworks Co., Ltd., Aberdeen, Scotland.
Dekorit	PF, t	Dr. F. Raschig, G.m.b.H., Ludwigshafen, Germany.
Dilecto	PF, 1	Continental-Diamond Fibre Co., Newark, Del.
Dioferrit	Px	Kausch.
Dobsoid	F, C	John Dobson, Ltd., Milnthorpe, England.
Dorcasine	C	Charles Horner, Ltd., England.
Dorex	PF	Dorex, Paris, France.
Dulux	D	E. I. du Pont de Nemours & Co., Philadelphia, Pa.
Dumold	O, Px, m	du Pont Viscoloid Co., Arlington, N. J.
Duo-lite	SG	Duplate Corporation, Pittsburgh, Pa.
Duosine	F	W. & G. Baird, Ltd., London, England.
Duplate	SG, Px	Duplate Corp., Pittsburgh, Pa.
Dura C	PF, s	Chemical Markets, **30**, 40, 1932.
Duranoid	PF, with shellac	Specialty Mfg. Co., Hoosick Falls, N. Y.
Durax	PF	Isola-Werke, Düren, Germany.
Durez	PF, m, f, l, s	General Plastics, Inc., North Tonawanda, N. Y.
Durite	PF, m, f, l, s	Stokes & Smith Co., Philadelphia, Pa.
Durium	PF, s, records	Durium Products Corp., New York, N. Y.
Duroid	PF	Bakelite Co., France.
Durolit	PF, t	Société de Duroid, Enghien, France.
Durophene	PF, s, m	Scott, Bader & Co., London, WC 2, England.
Duroware	UF, F, from Beetle	U. S. A.
Dux	D	Nobel Chem. Finishes, Ltd., Slough, England.
Ebenit	X	Établissements Grivolas, Paris, France.
Ebonestos	F	Ebonestos Insulators, Ltd., London, England.
Eburin	X	Hemming, 179.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
ECA	C, F	Bruggemann & Cia., Mexico.
Ecaille	PF, t	Labs. Indus. d'Asnières, Paris, France.
Elastica	SG (resin core)	I. G. Farbenindustrie, Frankfurt a./M., Germany.
Elastolith	PF, t	Herold A.G., Hamburg, Germany.
Electrobestos	X, cold mold	**Hemming,** 179.
Electroine	?	Établissements Grivolas, Paris, France.
Electrolit	?	Établissements Grivolas Paris, France.
Electrose	X	Insulator Mfg. Co., Brooklyn, N. Y.
Elephantide	lamin. board	Mica & Insulating Supplies Co., England.
Elfenbeinmaché	papier maché	**Kausch.**
Elfenite	resin adhesive	C. Werfel,
Ellinol	F	Ellison Insulations, Ltd., Birmingham, England.
Ellmar	F	Ellmar Mouldings Co., Birmingham, England.
Elo	PF, s, m	Birkby's, Liversedge, Yorkshire, England.
Emür	Px, F	Eberhard Mueller, Remscheid, Germany.
Endura	UF, F, from Beetle	**Plastics, 3,** 606, 1927.
	PF, t	see Juvelith
	?, m	English Plastics, Ltd., London, England.
Ergolith	C	McLeod & McLeod, London, England.
Erinite	resins	Erinoid, Ltd., Stroud, Gloucestershire, England.
Erinofort	CA ?	Erinoid, Ltd., Stroud, Gloucestershire, England.
Erinoid	C	American Plastics Corp., New York, N. Y.
Erinol	resin intermediates	Erinoid, Ltd., London, England.
Esbrilith	C, f	Rheinisches Farbwerk, Berlin, Germany.
Eshalite	B	Marzahn & Fritsch.
Esslinger Zellglass	V, P	Langheck & Co., Esslingen, Germany.
Esténite	B	**Kausch.**
Estralit	PF	**Plastics, 6,** 705, 1930.
Eswelit	asbestos-fill	Siemens-Schuckert Werke, Berlin, Germany.
Euboolith	?	Soc. anon. Euboolith, Paris, France.
Fabroil	PF, l, gears	General Electric Co., Schenectady, N. Y.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(Continued)

Name	Description	Manufacturer or reference
Fabrolite	PF, m	Commercial Utilities, Ltd., London, England.
Fantasit	C	Rhein. Westfäl. Sprengstoff A.G., Troisdorf, Germany.
Faturan	PF, t	Dr. H. Traun u. Söhne, Hamburg, Germany.
Fermit	?, m	Gummi-Ztg., **45**, 1010, 1931.
Ferrozel	PF, ?, l	Deutsche Ferrozell Ges., Augsburg, Germany.
Fiber Diamond	?	Dermatine, Ltd., London, England.
Fiberloid	Px, f	Fiberloid Corp., Indian Orchard, Mass.
Fibestos	CA	Fiberloid Corp., Indian Orchard, Mass.
Fimielite	PF	Plastics, **6**, 587, 1930.
Firmoid	F, Px, CA, coatg	Bluemel Bros., Ltd., Wolston, England.
Flaka Kapseln	CA, bottle caps	Kalle & Co., A.G., Wiesbaden-Biebrich, Germany.
Foord's Casein Plastic	C, pulv. coconut shells	
Formalite	PF	Bakelite, Ltd., Greet, England.
Formapex Miocarta	?	Mica & Insulating Supplies Co., England.
Formica	PF, l	Formica Insulation Co., Cincinnati, Ohio.
Formite	PF, t	Bakelite, Ltd., Greet, England.
Formolit	X	Alex. M. Nustukoff, Moscow, U. S. S. R.
Formolit	?, m	Hamburger Gummi Waren Compagnie, Hamburg, Germany and New York, N. Y.
Futurit	?	Kabelfabrik u. Draht Industrie, Vienna, Austria.
Galakerite	C	Soc. Ital. Galakerite, Milano, Italy.
Galalith	C	Intern. Galalith Ges., Harburg, Germany.
Galapol	C, f, s	Galalith, Ltd., London, England.
Galatix	C, F	Lumos & Co., London, England.
Galliperle	C	Cie. Générale d'Électricité Paris, France.
Gansolite	?	Gansolite, Ltd., Nijkerk, Holland.
Gaudafil	V, P	U. S. P., 1,688,457.
Geaphtal	GP	Allgem. Elektr. Ges., Germany.
Geloid	X, gelatine pl.	Germany.
Gesundheits-Pass	Px, F	Braun & Co., Berlin, Germany.
Glider	F, CA, ?, molded	A. W. Kanis, London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Globerite	C	Soc. Indus. Globerite, Milano, Italy.
Glorit	C	Schiel a Spol., Sternberg, Czechoslovakia.
Glutoid	gelatine caps	Transparentfolien, 283.
Glyptal	GP	General Electric Co., Schenectady, N. Y.
Glyptanite	GP and mica	Micanite & Insulators Co., Walthamstow, England.
Gramaphoid	sound records	General Plastics Corp., London, SE 13, England.
Granitol	fabric decor w. celluloid	Deutsche Pluviusin A.G., Germany.
Gummite	bituminous	Mfr. d'Isolants et Objets, Moulés, France.
Gummon	PF, m, cold-mold	Rhein. Westfäl. Sprengstoff A.G., Troisdorf, Germany.
Haefelyte	C, PF, t	Emil Haefely & Cie., Basel, Switzerland.
Hafo	P, gelatine	Folien und Flitterfabrik, Hanau, Germany.
Hagolit	CA, ?	Gebr. Eckert, Nürnberg, Germany.
Hai-Ho	Px, f	Hainich-Holz, G.m.b.H., Langensalza, Germany.
Haimanite	albumen base	Kausch.
Halex	?, ware	British Xylonite Co., London, England.
Halizite	PF, W	Halazite Corp., New York, N. Y.
Halolume	CA, F	British Elect. Installations Co., London, England.
Hares	PF, m	Roemmler A.G., Spremberg, Germany.
Haresit	PF, s	Roemmler A.G., Spremberg, Germany.
Harex	PF, l	Roemmler A.G., Spremberg, Germany.
Harlequin	UF, F, from Beetle	England.
Hastra	C	Hastra Kunstharz Presswerk, Vienna, Austria.
Haveg	PF, m, t	Saeureschutz Ges., Berlin, Germany. Haveg Corp., Newark, Del.
Hecolite	Px, dentures	Heko-Werke., Berlin, Germany.
Hekolith	Px	Heko-Werke., Berlin, Germany.
Heliosit	PF, ?, insul. resins	Kontakt-Römmler A.G., Frankfurt a./M., Germany.
Heliozell	V, P	Feldmühle Papier u. Zellstoffwerke, Stettin, Germany.
Heraklith	B	Kunstst., **21**, 124, 1931.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Herculite	X, m	Colasta Co., Hoosick Falls, N. Y.
Herkolite	?	General Electric Co., Schenectady, N. Y.
Herolith	PF, t	Herold A.G., Hamburg, Germany.
Hightensite	?	Brit. Plastics, **2**, 280, 1930.
Hornit	C	Gottfried Probst, Nürnberg, Germany.
Hornmaché	lam. paper	Kausch.
Hurtigsche Holzmasse	wood, water-glass	Kausch.
Hyalin	Px	
Hycoloid	Px, CA, tubes & bottles	Hygienic Tube & Container Co., U. S. A.
Hyli	Px, F, ware	Hygienische Ind. Ostertag, Ludwigsburg, Germany.
Iberolithe	PF	Soc. l'Orolithe, Rueil, France.
I.C.I. Moulding Powders	PF, m	Imper. Chem. Ind., Ltd., London, England.
Idelite	PF	Bakelite, Ltd., London, England.
Idytol	PF	Rev. Gén. Mat. Plast., **8**, 295, 1932.
Inda	C, f	Amer. Machine & Foundry Co.. Brooklyn, N. Y.
Indestructo	SG, Px	Indestructo Glass Corp., Farmingdale, N. Y.
Indurite	PF, m	Indurite Sales, Ltd., London, England.
Infuselax	UF, lacquer	Beetle Products Co., London, England.
Infusite	B	Mfr. d'Isolants et Objets Moulés, France.
Inlite	X, f	Inland Mfg. Co., Dayton, Ohio.
Inodite	see Ondonita	
Insulate	X	Insulation Mfg. Co., Brooklyn, N. Y.
Insulit	W, wall board	Backus-Brooks Co., U. S. A.
Insuloid	CA, P, sheeting	Harold Levey, New Orleans, La.
Isogalithe	C	Garraud, Tailleburg, France.
Isolanite	B	Kausch.
Isolemite	B, talc & mag. silicate	
Isolid	PF	Société Française, Vitry, France.
Isolierstahl	PF	Plastics, **6**, 705, 1930.
Isolit	PF, l	Société Française, Lyon, France.
Isolithe	PF, ?	Société Beguin, Paris, France.
Isoloid	CA	Charles Martin, Levallois, France.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Isophan	P, ethyl cell	Cellonwerke, Charlottenburg, Germany.
Ivaleur	Px, F	Celluloid Corp., Newark, N. J.
Ivoirine	X, gelat. base	
Ivoit	PF, t	Kunstharzfabrik Dr. F. Pollak, Vienna, Austria.
Ivorax	PF, t	Herold A.G., Hamburg, Germany.
Ivoris	F	French Ivory Products, Ltd.,
Ivory Cross	F, CA, ?, molded articles	A. W. Kanis, London, England
Ivrit	PF, t	Établissements Kuhlmann, Paris, France.
Ivrite	PF	Soc. anon. Ivra, Torino, Italy.
Ivryne	C	Établissements Feuillant,
Ixolain	PF, dentures	Plastics, **3**, 552, 1927.
Jacelite	F	J. A. Crabtree & Co., Walsall, England.
Jarax	PF, 1	Jaroslaw's Glimmer-Waren Fab., Berlin, Germany.
JMS	?	Chemie. u. Technik JMS, Hamburg, Germany.
Joanite	PF, t	Joanite Co., Brooklyn, N. Y.
Jurid	?, m, asbestos filler	Kirchbach, Germany.
Juvelith	PF, t	Kunstharzfabrik Dr. F. Pollak, Vienna, Austria.
Kalanite	insulator	Callender's Cable & Const. Co., London, England.
Karben	see Kupren.	
Karbolite	PF, with naphtha sulphonic acid	Plastics, **2**, 391, 436, 1926.
Karolith	C, f, m	American Plastics Corp., New York, N. Y.
Kasinoid	C, ?, F	A. W. Kanis, London, England.
Kelacoma	UF, m, F	Kelacoma, Ltd., Welwyn Garden City, England.
Kellite	PF	Kellogg Switchboard & Supply Co., Chicago, Ill.
Keralon	C	Rev. Gén. Mat. Plast., **8**, 87, 1932.
Kerasolith	?	Keramchemie Berggarten, Giessen, Germany.
Kerit	C, F	Internat. Galalith Ges., Harburg, Germany. Galalith Ltd., London, England.
Keronyx	C	Aberdeen Combworks Co., Ltd., Aberdeen, Scotland.
K-gutta	insulator	Rev. Gén. Mat. Plast., **8**, 188, 1932.
Kinonglas	SG, Px	N. Kinon, Aachen, Germany.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(Continued)

Name	Description	Manufacturer or reference
Kleko	gel. bott. caps	Kleko Flaschenverschluss Fab., Frankfurt, Germany.
Kodaloid	Px, film	Eastman Kodak Co., Rochester, N. Y.
Kodapak	CA, P	Eastman Kodak Co., Rochester, N. Y.
Kopan	PF, m, s	Kunstharzfabrik Dr. F. Pollak, Vienna, Austria.
Koraton	PF, t	Wedig & Reuss, Eilenburg, Germany.
Kornomit	X	Kornomit A.G., Skagen, Denmark.
Kupren	?	Electr. Werke Lonza, Basel, Switzerland.
Kyloid	C	Kyloid Co., Muskegon, Mich.
Lacanite	PF	American Record Corp., Scranton, Pa.
Laccain	PF	Louis Blumer, Zwickau, Germany.
Lacrinoid	F, artific. horn	Lacrinoid Products, Ltd., London, England.
Lactilith	C, f	Charles C. Fitzroy, London, England.
Lactite	C, hydr. casein, borax, alum, starch	
Lactitis	C, metallic caseinate	
Lactoid	C	British Xylonite Co., England.
Lactoite	C, Px	France.
Lactolithe	C, f	Glogau & Cie., Vitry, France.
Lactonite	C, f	British Lactonite Co., London, England.
Lactophane	C, P	Poyser Advert. Agency, London, England.
Laculose H	GP	Grindley & Co., London, England.
Laetélite	C	**Rev. Gén. Mat. Plast., 8,** 87, 1932.
Laminol	PF, 1	Ellison Insulations, Ltd., Birmingham, England.
Lapisite	B	Lapisite Marble Products Co., Portslade, England.
Lennite	PF, m, dentures	Ohio Chem. & Mfg. Co., Cleveland, Ohio.
Leukorit	PF, t	Dr. F. Raschig, G.m.b.H., Ludwigshafen, Germany.
Lewisol	D, lacq. gums	John D. Lewis, Providence, R. I.
Lignat	W, org. binder	Christof & Unmack, A.G., Oberlausitz, Germany.
Lignostone	W	Kausch.
Linga-Longa	UF, F, from Beetle	Beatl Sales Co., London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Linolin	?, insulation	Lindsay & Williams, Ltd., Manchester, England.
Linsden	F	Brit. Thomson-Houston Co., London, WC 2, England.
Lissen	F	Lissen, Ltd., Islesworth, England.
Lithene	CA, m	Plastic Moulding Co., Ltd., London, England.
Lonarit	CA, m	Lonarit Ges., Berlin, Germany.
Lorival	?, f	Lorival Mfg. Co., Ltd., Southall, England.
Lor-Wal-Lith	PF, t	Chemie. u. Technik, JMS, G.m.b.H., Hamburg, Germany.
Lucent Reel	Px, film scrap	Rex Campbell & Co., England.
Lucienit	PF, t	Lucien Eilertsen,
Lucite	Px, F	du Pont Viscoloid Co., Arlington, N. J.
Lugdomite	CA	Société Lyonnaise de Celluloide, Lyon, France.
Luglas	SG, (resincore)	Röhm & Haas A.G., Darmstadt, Germany.
Lumarith	CA, m	Celluloid Corp., Newark, N. J.
Lupinite	C	**Plastics, 3,** 674, 1927.
Luxalin	Px	see Pyradiolin.
Luxalith	C	Société l'Oyonnaxienne, Oyonnax, France.
Luxan	UF, s	Luxite, Inc., Boston, Mass.
Luxite	UF, m	Luxite, Inc., Boston, Mass.
Luxolith	C	Société l'Oyonnaxienne, Oyonnax, France.
Macoid	Px, dip finish	Crawford, MacGregor & Canby, Dayton, Ohio.
Magranit	PF, l	Australia.
Maizewood	W, cornstalk board	**Cellulose, 1,** 10, 1930.
Maizolith	W, cornstalk plastic	**Rev. Gén. Mat. Plast., 6,** 461, 1930.
Makalot	PF, s, m	Makalot Corp., Boston, Mass.
Makelite	P, cellulose container substance	American Can Co., New York, N. Y.
Maleaze	PF	**Rev. Gén. Mat. Plast., 8,** 157, 1932.
Mandem	F	McLeod & McLeod, London, England.
Manusolite	?	Soc. d'Isolants et Objets Moulés, France.
Marbalin	F	Federal Cutlery Co., New York.
Marbelle	F	Ebonestos Insulators, Ltd., London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Marblene	CA ?, sheeting	Waite & Son, Ltd., London, England.
Marblette	PF, t	Marblette Corp., Long Island City, N. Y.
Marbloid	CA ?, sheeting	Speights, Ltd., London, England.
Marbolith	PF, t	Herold A.G., Hamburg, Germany.
Margolit	cold-mold	Ver. Isolaterenwerke A.G.,
Marvelex	SG	England.
Masa	PF, f	Masa G.m.b.H., Berlin, Germany.
Masonite	W, wall board	Mason Fiber Co., Laurel, Miss.
Mastolite	PF, 1	Symentis Products, Ltd., Eccles, England.
Masuron	CA, f, m	John W. Masury & Sons, Brooklyn, N. Y.
MEC	CA, F, molded articles	Minerva Engineering Co., London, England.
Megohmax	PF, ?, insulat.	John Moores & Co. Lancashire, England.
Meghomior	PF, ?, insulat.	John Moores & Co., Lancashire, England.
Meghomit	PF, ?, insulat.	John Moores & Co., Lancashire, England.
Meigsoid	sugar-aniline	Meigsoid Corp., Jersey City, N. J.
Mergalithe	C	de Charraud, Rueil, France.
Metakaline	PF	Rev. Gén. Mat. Plast., **8**, 157, 1932.
Metduro	PF, t	Metduro, Ltd., London, England.
Micafolium	PF	Plastics, **6**, 705, 1930.
Micalas	lam. mica	Soc. Française le Micalas,
Micanite	lam. mica	John Moores & Co., Salford, England.
Micarta	PF, 1	Westinghouse Elect. & Mfg. Co., Pittsburgh, Pa.
Micolite	PF, glutens & phenol	Paul Edgard Basset, Paris, France.
Midgema	F	Midland Gear Case Co., Ltd., Birmingham, England.
M. L.	UF, F, from Beetle	Beatl Sales Co., London, England.
Moldarta	PF, UF, m	Westing. Elect. & Mfg. Co., Pittsburgh, Pa.
Moldite	CA	American Cellulose & Chem. Mfg. Co., New York, N. Y.
Monit	V, viscose plastic	Gummi-Ztg., **45**, 1242, 1931.
Monolite	X	Monowatt Electric Corp., New York, N. Y.
Moskalit	C	Moscow State Chem. Trust, Moscow, U.S.S.R.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Mouldensite	PF, m	Damard Lacquer Co., Greet, England.
Mouldings of Merit	F	Insulators, Ltd., Edmonton, England.
Mouldrite	PF, m	Croydon Mouldrite, Ltd., Croydon, England.
Mowilith	D, vinyl resin	Hoechst Farbwerke, I.G., Bingen a./R., Germany.
Mycalex	mica-glass	General Electric Co., Schenectady, N. Y.
Nacara	Px	Fiberloid Corp. Indian Orchard, Mass.
Nacrolaque	CA, sheeting	Jos. H. Meyer Bros., Brooklyn, N. Y.
Nally	F	Nally, Ltd., England.
Nalo	V, sausage casing	Kalle & Co., Wiesbaden-Biebrich, Germany.
Neolith	C	Deutsche Kunsthorn Ges., **Gummi-Ztg., 45,** 935, 1931.
Neolith	PF	**Plastics, 6,** 705, 1930.
Neophan	CA, P	Cellonwerke, Charlottenburg, Germany.
Neoresit	PF, s, m	Aug. Nowack A.G., Berlin, Germany.
Nestorite	PF, m, s	James Ferguson & Sons, Ltd., Merton Abbey, London, England.
Neutex	SG, CA	Sicherheitsglas Neutex, Aachen, Germany.
Nevalyte	F	Myers, Ltd., Walthamstow, England.
Newtex	SG, CA	England.
Nie-Splitt	SG	Dewag Deutsche Warenvertriebs G.m.b.H., Berlin, Germany.
Niloid	Px	H. Bossi.
Nixinoid	gel. plastic	H. Bossi.
Nixonoid	Px, f	Nixon Nitration Works, Nixon, N. J.
Nobeline	PF, t	Sicaloid, Ltd., London, England.
Norgine	X, alginates from seaweed	**Plastics, 6,** 656, 1930.
Norloc	F, m	Norton Labs. Co., Lockport, N. Y.
Nosplita	F	Ambri-Verwaltung, Berlin, Germany.
Noveloid		Imp. Chem. Inds., London.
Noveltic	Px, F	K. F. Mayer, London, England.
Novite	PF, m	Imper. Chem. Industries, Ltd., London, SW 1, England.
Novo-Heliophan	gel. foil	Gebr. Klotz, Goppingen, Germany.
Novolak	PF, s	Bakelite Corp., New York, N. Y.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Novolithe	CA	Société Bellignite, Bellignat, France.
Novoresit	resorcinol trioxymethylene	Aug. Nowack, Gautzen, Germany.
Novotext	PF, gears, fabric filling	**Plastics, 6,** 705, 1930.
Nuplax	O, ?	American Nuplax Corp., New York, N. Y.
Nymphrap Extra	CA ?, P	Sylvania Industrial Corp., Fredericksburg, Va.
Omegite	PF, m	Brit. Dyestuffs Corp., Ltd., Manchester, England.
Onazote	?, heat insul.	**Brit. Plastics, 2,** 242, 1930.
Ondoine	D, m	Soc. anon. Franç. du Ferodo, Paris, France.
Ondoita	?	Afcom, Ltd., London, England.
Opal	PF, t	see Ivoit.
Opalax	F, m	A. W. Kanis, London, England. Crayonne, Ltd., Bexley, Kent, England.
Orlak	PF, F	Chance Bros. & Co., West Smethwick, England.
Ornalith	PF, t	Herold A.G., Hamburg, Germany.
Orolithe	CA	Société d'Orolithe, Rueil, France.
Orthospan	CA	Medical Supply Assn., Ltd., London, England.
Oxygalalith	C	France.
Oyocetil	CA	Société l'Oyonnaxienne, Oyonnax, France.
Oyogalithe	C	Société l'Oyonnaxienne, Oyonnax, France.
Oyonnithe	C	Soc. Petit-Collin-Oyonnithe, Paris, France.
Ozaphane	?	Le Film Ozaphane, Paris, France.
Panelyte	PF, 1	Panelyte Co., Boston, Mass., and Trenton, N. J.
Panilax	insul. mater	Micanite & Insulators Co., Ltd., London, England.
Panolite	?	I. Paenson et Cie, Paris, France.
Pantolit	PF, t	Augsburger Kunstharz-Fabrik, Augsburg, Germany.
Papyroplast	?	**Brit. Plastics, 2,** 323, 1930.
Paragutta	rubber, wax, etc.	Bell Telephone Labs., New York, N. Y.
Paralac	D	Imper. Chem. Indus., Ltd., London, England.
Paralithe	D ?, t	Établissements Kuhlmann, Paris, France.
Parfait	Px, dentures	Parisien Chem. Co., Toledo, Ohio.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Patentlack	D	Louis Blumer, Zwickau, Germany.
Paxolin	PF	Micanite & Insulators Co., London, England.
Pearlite	CA, ?, sheeting	Speights, Ltd., London, England.
Pearloid	Px, sheeting	Jos. H. Meyer Bros., Brooklyn, N. Y.
Peralit	PF, P	**Plastics, 6,** 705, 1930.
Permacal	F, P	W. & G. Baird, Ltd., London, England.
Permaloid	Px, F	Celluloid Printers, Ltd., London, England.
Permanite	Px, F	Parker Pen Co., Janesville, Wis.
Pertinax	PF, l	Meirowsky & Co., Porz am Rhein, Germany.
Phenoid	PF, l	Mica Mfg. Co., Ltd., England.
Phenolic	PF, F	Amer. Record Corp., Scranton, Pa.
Phenolite	PF, l	National Vulcanized Fiber Co., Wilmington, Del.
Philite	F, UF, PF	N. V. Phillips Gloeilampenfab., Eindhoven, Holland.
Phobophene	from tannery waste	Westinghouse Elect. & Mfg. Co., East Pittsburgh, Pa.
Phonycord	?, record mat.	Phonycord G.m.b.H., Berlin, Germany.
Picaroid	Px, sheet-cover of articles	Picaroid Process, Ltd., London, England.
Plaskalite	?	Chester, W. Va.
Plaskon	UF, m	Toledo Synthetic Products, Inc., Toledo, Ohio.
Plass	UF, t	Pollopas, Ltd., Nottingham, England.
Plastacele	CA, f	du Pont Viscoloid Co., Arlington, N. J.
Plastam	?	Société Lilloise Plastam, Lille, France.
Plastico	?	**Rev. Gén. Mat. Plast., 6,** 509, 1930.
Plastilume	CA, ?, F	W. V. Hutchinson, London, England.
Plastin	CA	Société des Matières Plastiques, Paris, France.
Plastine	CA	Société Nobel Française, Paris, France. Sicaloid, Ltd., London, England.
Plastopal	UF, s	Pollopas, Ltd., London, EC 1, England.
Plasto resin	?	Advance Solvents & Chem. Corp., New York, N. Y.
Plastose	PF	Afcom, Ltd., London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Plax	D	Plax Products, Ltd., London, England.
Plexigum	D, used in Luglas	Röhm & Haas A.G., Darmstadt, Germany.
Pliaphan	P, gel. foil	Langheck & Co., Esslingen, Germany.
Plioform	?	Goodyear T. & R. Co., Akron, O.
Pluviusin	UF	Kunstharzfabrik Dr. F. Pollak, Vienna, Austria.
Plyafix	C	Jos. Nathan & Co., Ltd., London, England.
Plynalith	C, CA	Isaac Frenkel, Paris, France.
Pollopas	UF, m, f	Kunstharzfabrik, Dr. F. Pollak, Vienna, Austria.
		Pollopas, Ltd., London.
		Venditor G.m.b.H., Berlin, Germany.
Pollopas-Platten	UF, l	Venditor G.m.b.H., Berlin, Germany.
Polyroc	?, t	Établissements Kuhlmann. Paris, France.
Porcellanite	C	Société de Charraud, Rueil, France.
Press Mass	CA, m	Amer. Brit. Chem. Supplies, Inc., New York, N. Y.
Pressmikanit	PF	Plastics, **6**, 705, 1930.
Presszell	PF	Plastics, **6**, 705, 1930.
Primalithe	C, f	Cie. de Procédés Plinatus, Paris, France.
Priscal	UF, t	Soc. anon. des Matières Plastiques, Paris, France.
Prisma	F	Mica Mfg. Co., Ltd., England.
Progilite	PF, m, s	Soc. Résines & Vernis Artificiels, Paris, France.
Prophopha	?	Produits Prophopha, France.
Protectoid	CA, P	Celluloid Corp., Newark, N. J.
Proteolite	C	Ind. Ital. della Proteolite, Milano, Italy.
Prystal	UF, t	Soc. Ind. des Matières Plast., Paris, France.
		Sicaloid, Ltd., London, England.
Pyradiolin	Px, sheeting	du Pont Viscoloid Co., Arlington, N. J.
Pyraheel	Px, heel cover	du Pont Viscoloid Co., Arlington, N. J.
Pyralin	Px, f	du Pont Viscoloid Co., Arlington, N. J.
		Canadian Industries, Ltd., Montreal, Canada.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Pyroplax	X, cold-mold	Cutler Hammer, Inc., Milwaukee, Wis.
Radite	Px, F	Sheaffer Pen Co., Fort Madison, Iowa.
Rayolith	F	French Ivory Products, Ltd., England.
Redmanol	PF, m	Bakelite Corp., New York, N. Y.
Reflite	m	Dante Badino.
Reliance	Px, CA, F	Reliance Nameplates, Ltd., Twickenham, England.
Repetit	PF	Plastics, **6**, 705, 1930.
Resan	PF, f	Bakelite Corp., New York, N. Y.
Resanit	PF, t	Kunstharzfabrik Resan, Mosbierbaum, Germany.
Resin AH AW1, AW2	X, polymerized styrol	CGP **28**, 15366, 1931.
Resinit	PF, s, t	Knoll & Co., Ludwigshafen, Germany.
Resinol	PF, s, m	Dr. F. Raschig, G.m.b.H., Ludwigshafen, Germany.
Resinox	PF, s, m	Resinox Corp., New York, N. Y.
Resin Superba	PF	Plastics, **5**, 38, 1929.
Resin Superbo	PF	Plastics, **6**, 38, 1929.
Resistan	PF, heat resist.	Kontakt-Römmler A.G., Frankfurt a./M., Germany.
Resoglaz	styrol	Advance Solvents & Chem. Corp., New York, N. Y.
Resopal	UF, m	Römmler A.G., Spremberg, Germany.
Resovin	vinyl resin denture	S. S. White Dental Mfg. Co.
Rexalith	C	Société la Rexalith, Paris, France.
Reynolite	F	Reynolds Spring Co., Jackson, Mich.
Rezelite	PF	Cussons Sons & Co., Manchester, England.
Rezinel	D, resins	Glyco Products Co., Inc., Brooklyn, N. Y.
Rezyl	GP	American Cyanamid Co., New York, N. Y.
Rhodialine	CA, P	Soc. des Usines Chim. Rhone-Poulenc, Paris, France; and
Rhodoid	CA, f, m	May and Baker, Ltd., London, SW 11, England.
Rhodophane	CA, P	
Richelain	UF, F, ware	Richardson Co., Melrose Park, Ill.
Ricolit	?	Suedd. Isolatorenwerke, Freiburg, Germany.
Ripolin	?	Rev. Gén. Mat. Plast., **8**, 319, 1932.
RJR	F, C, molded	Afcom, Ltd., London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Roanoid	UF, F, from Beetle	Roanoid, Ltd., Glasgow, Scotland.
Roburine	?, m	Soc. d'Isolants et Objets, Moulés, France.
Rockite	PF, s, m	Rockhard Resins, Ltd., London, England.
Rockshell	PF, s, m	Rockhard Resins, Ltd., London, England.
Rollistic	F	Rolls Razor Co., London, England.
Ronilac	UF } for injection molding	Société La Ronite, Seine, France.
Ronisol	PF } for injection molding	Société La Ronite, Seine, France.
Ronite	CA } for injection molding	Société La Ronite, Seine, France.
Rucel	D, rubber-cell mixture	Plax Products, Ltd., London, England.
Runerit	PF, l, m	Electro-Isolier-Industrie, Wahn, Germany.
Safetee Glass	SG, Px	Safetee Glass Co., Wissinoming, Pa.
St. Bernard	F, molded	A. W. Kanis, London, England.
Sakaloid	X, from sugar	Indust. Sugar Prod. Corp., New York, N. Y.
Samson-Celluloid	Px, film	Celluloid Corp., Newark, N. J.
Sanophon	F	Ozonol Laboratories, London, England.
Satolite	C	Sankyo Kabushiki Kaisha, Tokyo, Japan.
Schellan	UF, s	Kunstharzfabrik Dr. F. Pollak, Vienna, Austria.
Schellit	PF, t	Kunstharzfabrik Dr. F. Pollak, Vienna, Austria. and Établissements Kuhlmann, Paris, France.
Securex	SG	Germany.
Securite	CA	Cie. Petit-Collin-Oyonnithe, Paris, France.
Seracelle	V, sheeting	Courtaulds, Ltd., London, England.
Setabonite	resin-rubber	Mfr. d'Isolants et Objets Moulés, France.
Setacegeite	PF, m	Mfr. d'Isolants et Objets Moulés, France.
Sicalite	C	Société Nobel Française, Paris, France; Sicaloid Ltd., London, England.
Sicoid	CA	Société Nobel Française, Paris, France; Sicaloid Ltd., London, England.
Sidac	V, P	Sylvania Indust. Corp., Fredericksburg, Va.
Sidac	V, P	Soc. Ind. de la Cellulose, Ghent, Belgium.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Sidac-Isol	V, P	Soc. Ind. de la Cellulose, Ghent, Belgium.
Sigaleos	PF	Plastics, **6**, 589, 1930.
Silvaplana	P, gelatine	Folien-u. Flitterfabrik, Hanau, Germany.
Similex	PF, t	Labs. Indust. d'Asnières, Paris, France.
Similit	PF, t	Labs. Indust. d'Asnières, Paris, France.
Solidite	F, m, pitch-asbestos	Solidite & Synthetic Mouldings, Ltd., London, England.
Solith	PF, t	Rejal a Spol., Prague, Czechoslovakia.
Souvelo	F, UF, ?, ware	Souvenir Mfg. Co., Birmingham, England.
Spauldite	PF, l, gears	Spaulding Fiber Co., N. Rochester, N. H.
Splintex	SG, CA	Splinterless Glass Co., Ltd., Teddington, England.
Sportsman	F	A. W. Kanis, London, England.
Stabilite	?	Soc. Grandgener, Perreux, France.
Starkware	UF ?, ware	U.S.A.
Sterilin	CA, surg. tissue	Germany.
Streetly	UF, F, ware of Beetle, etc.	Streetly Mfg. Co., Ltd., London, England.
Superisolite	PF	Plastics, **6**, 587, 1930.
Super-Micanite	X, glyptal bond mica filler	Brit. Plastics, **2**, 444, 1931.
Sylphrap	CA ?, P	Sylvania Indus. Corp., Fredericksburg, Va.
Sylvania	V, P	Sylvania Indus. Corp., Fredericksburg, Va.
Syn-phorm	D	Blackburn & Oliver, England.
Synthaform	F	Synthaform, Berlin, Germany.
Syntholite	PF ?	Soc. anon. la Syntholite, Paris, France.
Syrolith	C	Gummi-Ztg., **45**, 935, 1931.
Tantoid	X, m	W. T. Tant & Co., Ltd., England.
Tapa	? molded	W. J. Charlesworth, Ltd., Birmingham, England.
Taumalit	PF, F	Isopresswerk, Berlin, Germany.
Teglac	D, lacquer resin	American Cyanamid Co., New York, N. Y.
Tego	D, adhesives	Th. Goldschmidt. A.G., Essen, Germany.
Telconax	bituminous	Teleg. Const. & Maint. Co., London, England.
Telconite	insulation	Teleg. Const. & Maint. Co., London, England.
Telenduron	?, m	Thomas de la Rue & Co., London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Tenalan	PF	**Plastics, 6,** 705, 1930.
Tenazit	PF	Allgem. Elect. Ges., Berlin, Germany.
Tenegrine	?	Société Rhodiaseta., Paris, France.
Tenex	CA, m	Tennessee Eastman Corp., Kingsport, Tenn.
Tensulam	?, m	Benj. Wiggins & Co., Ltd., England.
Tepperite	styrol denture	Martin Rubber Co., Long Island City, N. Y.
Tetrolith	?	Kunsthornwerke Teterow, Mecklenburg, Germany.
Textal	V, P, coated alumin. foil	Aluminium Walzwerke A.G., Singen, Germany.
Textit	F, acid-proof	Cable Mfg. Co., England.
Textolite	PF, f, m, l	General Electric Co., Schenectady, N. Y.
Text-Tiles	UF ?, tiles	Kelacoma, Ltd., Welwyn Garden City, England.
Thermasote	W, fiber board	Agasote Millboard Co., Trenton, N. J.
Thermoplax	X, cold-mold	Cutler-Hammer, Inc., Milwaukee, Wis.
Thesit Supra	?, m	Presswerk A.G., Essen, Germany.
Thiobonite	X, rubber and resins	**Plastics, 7,** 19, 1931.
Thiojectite	? for inject molding	**Plastics, 7,** 19, 1931.
Thiokol	olefine-polysulphide	Thiokol Corp., Yardville, N. J.
Thiolite	PF	Soc. Levy, Samuel, et Levy, Joinville, France.
Thorax	SG	Mühlig Union, Czechoslovakia.
Tortaloid	CA, F	Fiberloid Corp., Indian Orchard, Mass.
Transcetic	P	**Plastics, 7,** 619, 1931.
Transflex	P, gelatine	Folien-u. Flitterfabrik, Hanau, Germany; Central Import Co., Chicago, Ill.
Transparenta	CA, P	Transparenta G.m.b.H., Berlin, Germany.
Transparit	V, P	Wolff & Co., Walsrode, Germany.
Transphan	P, cuprammonium.	Bemberg, A.G., Wupperthal, Germany.
Trefoil	PF	Bakelite, Ltd., London, England.
Trelit	Px	Norway.
Triacel	CA, P	**Chem. Weekblad, 29,** 167, 1932.
Triolin	Px, floor covering	**Brit. Plastics, 2,** 225, 1930.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Triplex	O, Px, SG	Triplex Safety Glass Co. of North America, Clifton, N. J.
Trolit	Px, CA	Rheinisch-Westfälische Sprengstoff A.G., Troisdorf, Germany; and Venditor G.m.b.H., Berlin, Germany.
Trolit-Spezial	PF, m	
Trolitan	PF, m	
Trolitan H	UF, m	
Trolitan S	PF, m	
Trolitax	PF, l	
Trolitul	Styrol	
Trolon	PF ? t	
Trolon-Platten	PF, l	
Tufnol	PF, l, f	Ellison Insulations, Ltd., Birmingham, England.
Turax	PF	**Plastics 6,** 705, 1930.
Turbax	PF, l	Jaroslow's Glimmer-Waren Fabrik, Berlin, Germany.
Turbonit	PF, m	Jaroslow's Glimmer-Waren Fabrik, Berlin, Germany.
Ultraphan	CA, P	Lonza, Weil am Rhein, Germany.
Ultrasit	PF, t	Chem. Fabrik Ambrasit, Vienna, Austria.
Ultrastrip	F, sheeting	Troughton & Young, Ltd., London, England.
Unex	SG	Unex Safety Glass Co., London, England.
Unyte	UF, m	Unyte Corp., New York, N. Y.
Uralite	UF, m	Soc. Résines et Vernis Artificiels, Paris, France.
Urocristal	UF, m	
Utilit	PF, t	Augsburger Kunstharzfabrik., Augsburg, Germany.
Velskin	?, sheeting	Albion Shades, Ltd., England.
Veryx	UF	Edgard Israel, France.
Vetroloid	?, sheeting	Albion Shades, Ltd., England.
Viaconit	m	Ver. Isolatorenwerke A.G., Germany.
Victron	styrol mold powder	Naugatuck Chem. Co., New York, N. Y.
Vigorit	PF, t	Dr. F. Raschig, G.m.b.H., Ludwigshafen, Germany.
Vinylite	M, vinyl resin	Carbide & Carbon Chem. Corp., New York, N. Y.
Viralite	CA, coated netting	Darlington Fencing Co., Ltd., London, EC 4, England.
Viscacelle	V, P	Courtaulds, Ltd., London, England.
Visco	V, P	Chem. Werke Visco, Aussig, Czechoslovakia.
Viscocelle	V, P	Courtaulds, Ltd., London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
Viscoloid	Px, f	du Pont Viscoloid Co., Leominster, Mass.
Visking	V, sheeting	Visking Corp., Chicago, Ill.
Vitalite	CA	New York Wire Cloth Co., New York, N. Y.
Vitreo-Colloid	CA, P, closures	J. M. Newton Vitreo-Colloid, Ltd., London, England.
Vitrex	CA, coated netting	Transparentfolien, 284.
Vitrocelle	V, P	Dalle Frères et Lecomte, Bousbecque, France.
Vitrolux	? cellulose	W. & G. Baird, Ltd., London, England.
Vitrophan	P, gelatine	Continental Gelatine Ind.. Michelstadt, Germany
Vortex-Burt	PF, F	Vortex Cup Co., Chicago, Ill.
Vydon	vinyl denture	L. S. Smith & Son Pittsburgh, Pa.
Wahnerit	PF, 1	Elect. Isol. Indust., Wahn, Germany.
Walo-Kapseln	V, bottle caps	Wolff & Co., Walsrode, Germany.
Walonerit	?, m	Elect. Isol. Indust., Wahn, Germany.
Wandrite	PF	H. Wandrowsky, Berlin, Germany.
Waterlite	styrol	Watertown, N. Y.
Wenjazit	PF, t	Kunst-Rohstoff A.G., Hamburg, Germany.
Xetal	SG, CA	England.
Xilite	PF, t	Plastics, **6**, 589, 1930.
Xylolith	B, magnesia flooring	Deutsche Xylolith Platten Fabrik, Germany.
Xylonite	Px, f	British Xylonite Co., Ltd., London, England.
YZ	F	Henry Howell & Co., London, England.
Zalmite	W, shells burlap, etc.	Simmons & Co., Kenosha, Wis.
Zellhaut	P	Chem. Fab. Heyden, Dresden, Germany.
Zellugol	CA	Kunstst., **21**, 87, 1931.
Zoolite	C, f	Soc. Polenghi Lombardo, Codogno, Italy.
	B, magnesite for molding.	M. E. Converse & Son Co., Winchendon, Mass.
	C, m	Sarvis Osakeyhtio, Tammersfors, Finland.
	CA	Fabbrica Bonelli, Italy.
	CA, m	Acetate Products Corp., Ltd., London, England.

TABLE IX.—PLASTIC PRODUCTS AND PRODUCERS.—(*Continued*)

Name	Description	Manufacturer or reference
	Px, CA, film	du Pont Film Mfg. Corp., Parlin, N. J.
	Px, CA, film	Eastman Kodak Co., Rochester, N. Y.
	P	Natural Products Conversion Corp.,
	PF	Magnasco Roggero & Co., Genoa, Italy.
	Px, plastics	Westfälisch-Anhaltische Sprengstoff A.G Berlin, Germany.
	SG, Px	Ford Motor Co., Detroit, Mich.
	SG	Johnston Glass Co., Hartford City, Ind.
	SG, Px	Libbey-Owens-Ford Glass Co., Toledo, Ohio.
	X, aldehyde resins	Consortium fur Electrochem. Ind., München, Germany.

TABLE X.—PLUNGER DISPLACEMENT OF SINGLE-ACTING PLUNGER[1]

Length stroke, inches		2	3	4	5	6	7	8	9	10	12
Diameter, inches	Area, square inch	Capacity per stroke, U. S. gallons									
½	0.196	0.002	0.003	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.010
⅝	0.307	0.003	0.004	0.005	0.007	0.008	0.009	0.011	0.012	0.013	0.016
¾	0.442	0.004	0.006	0.008	0.010	0.011	0.013	0.015	0.017	0.019	0.023
⅞	0.601	0.005	0.008	0.010	0.013	0.016	0.018	0.021	0.023	0.026	0.031
1	0.785	0.007	0.010	0.014	0.017	0.020	0.024	0.027	0.031	0.034	0.041
1⅛	0.994	0.009	0.013	0.017	0.022	0.026	0.030	0.034	0.039	0.043	0.052
1¼	1.227	0.011	0.016	0.021	0.027	0.032	0.037	0.042	0.048	0.053	0.064
1⅜	1.485	0.013	0.019	0.026	0.032	0.039	0.045	0.051	0.058	0.064	0.077
1½	1.767	0.015	0.023	0.031	0.038	0.046	0.054	0.061	0.069	0.077	0.092
1⅝	2.074	0.018	0.027	0.036	0.045	0.054	0.063	0.072	0.081	0.090	0.108
1¾	2.405	0.021	0.031	0.042	0.052	0.062	0.073	0.083	0.094	0.104	0.125
1⅞	2.761	0.024	0.036	0.048	0.060	0.072	0.084	0.096	0.108	0.120	0.144
2	3.142	0.027	0.041	0.054	0.068	0.082	0.095	0.109	0.122	0.136	0.163
2⅛	3.547	0.031	0.046	0.061	0.077	0.092	0.107	0.123	0.138	0.154	0.194
2¼	3.976	0.035	0.052	0.070	0.087	0.104	0.122	0.139	0.157	0.174	0.209
2⅜	4.430	0.038	0.058	0.077	0.096	0.115	0.134	0.153	0.173	0.192	0.230
2½	4.909	0.043	0.064	0.085	0.111	0.128	0.149	0.170	0.201	0.213	0.255
2¾	5.940	0.051	0.077	0.103	0.129	0.154	0.180	0.206	0.231	0.257	0.309
3	7.069	0.061	0.092	0.122	0.153	0.184	0.214	0.245	0.275	0.306	0.367
3¼	8.296	0.072	0.108	0.144	0.180	0.215	0.251	0.287	0.323	0.359	0.431
3½	9.621	0.083	0.125	0.167	0.208	0.250	0.292	0.333	0.375	0.417	0.502
3¾	11.04	0.096	0.143	0.191	0.239	0.287	0.335	0.382	0.430	0.478	0.574
4	12.57	0.109	0.163	0.218	0.272	0.326	0.381	0.435	0.490	0.544	0.653
4¼	14.19	0.123	0.184	0.246	0.307	0.368	0.430	0.491	0.553	0.614	0.737
4½	15.90	0.138	0.207	0.275	0.344	0.413	0.482	0.551	0.620	0.689	0.826
4¾	17.72	0.153	0.230	0.307	0.384	0.460	0.537	0.614	0.690	0.767	0.920
5	19.63	0.170	0.255	0.340	0.425	0.510	0.595	0.680	0.765	0.850	1.020
5¼	21.65	0.187	0.281	0.375	0.469	0.562	0.656	0.750	0.843	0.937	1.124
5½	23.76	0.206	0.309	0.411	0.514	0.617	0.720	0.823	0.926	1.029	1.234
5¾	25.97	0.225	0.337	0.450	0.562	0.674	0.787	0.899	1.011	1.124	1.348
6	28.27	0.245	0.367	0.490	0.612	0.734	0.857	0.979	1.102	1.224	1.469
6¼	30.68	0.266	0.398	0.531	0.664	0.797	0.930	1.062	1.195	1.328	1.593
6½	33.18	0.287	0.431	0.574	0.718	0.861	1.005	1.149	1.293	1.436	1.723
6¾	35.78	0.309	0.465	0.620	0.775	0.929	1.084	1.239	1.394	1.549	1.858
7	38.48	0.333	0.500	0.666	0.833	1.000	1.166	1.333	1.499	1.666	1.999
7¼	41.28	0.358	0.536	0.715	0.894	1.072	1.251	1.430	1.608	1.787	2.144
7½	44.18	0.383	0.574	0.765	0.956	1.148	1.339	1.530	1.721	1.913	2.295
7¾	47.17	0.408	0.613	0.817	1.021	1.225	1.429	1.633	1.837	2.042	2.450
8	50.27	0.435	0.653	0.870	1.088	1.306	1.523	1.741	1.958	2.176	2.611
8¼	53.46	0.463	0.694	0.926	1.157	1.389	1.620	1.851	2.083	2.314	2.777
8½	56.75	0.490	0.735	0.980	1.225	1.470	1.715	1.960	2.205	2.450	2.940
8¾	60.13	0.520	0.780	1.040	1.300	1.560	1.820	2.080	2.340	2.600	3.120
9	63.62	0.551	0.826	1.101	1.377	1.652	1.928	2.203	2.479	2.754	3.305
9½	70.88	0.612	0.918	1.224	1.530	1.836	2.142	2.448	2.754	3.060	3.672
10	78.54	0.680	1.020	1.360	1.700	2.040	2.380	2.720	3.060	3.400	4.080
10½	86.59	0.750	1.125	1.499	1.874	2.249	2.624	3.000	3.374	3.749	4.500
11	95.03	0.823	1.234	1.645	2.057	2.464	2.879	3.291	3.726	4.114	4.937
11½	103.9	0.899	1.349	1.799	2.248	2.698	3.148	3.597	4.047	4.497	5.396
12	113.1	0.979	1.468	1.958	2.448	2.938	3.422	3.917	4.406	4.896	5.875

[1] Courtesy of Baldwin Southwark Corporation.

TABLE XI.—CAPACITIES OF HYDRAULIC RAMS IN TONS[1]

Diameter	Pressure, pounds per square inch																					Gal. per inch	Gal. per foot	Area
	300	500	600	750	1000	1200	1500	1800	2000	2250	2500	2750	3000	3500	4000	4500	5000	5500	6000	6500	7000			
1	0.12	0.20	0.24	0.29	0.39	0.47	0.59	0.71	0.79	0.88	0.98	1.08	1.18	1.37	1.57	1.77	1.96	2.16	2.36	2.55	2.76	0.003	0.041	0.79
1½	0.27	0.44	0.53	0.66	0.88	1.06	1.33	1.59	1.77	1.99	2.21	2.43	2.65	3.09	3.53	3.98	4.42	4.86	5.30	5.74	6.19	0.008	0.092	1.77
2	0.47	0.79	0.94	1.18	1.57	1.88	2.36	2.83	3.14	3.53	3.93	4.32	4.71	5.50	6.28	7.07	7.85	8.64	9.42	10.2	11.0	0.014	0.163	3.14
2½	0.74	1.23	1.47	1.84	2.45	2.95	3.68	4.42	4.91	5.52	6.14	6.75	7.36	8.59	9.82	11.0	12.3	13.5	14.7	16.0	17.2	0.023	0.255	4.91
3	1.06	1.77	2.12	2.65	3.53	4.24	5.30	6.36	7.07	7.95	8.84	9.72	10.6	12.4	14.1	15.9	17.7	19.4	21.2	23.0	24.7	0.031	0.367	7.07
3½	1.44	2.41	2.89	3.61	4.81	5.77	7.22	8.66	9.62	10.8	12.0	13.2	14.4	16.8	19.2	21.6	24.1	26.5	28.9	31.3	33.7	0.042	0.500	9.62
4	1.88	3.14	3.77	4.71	6.28	7.54	9.42	11.3	12.6	14.1	15.7	17.3	18.8	22.0	25.1	28.3	31.4	34.6	37.7	40.8	44.0	0.054	0.653	12.6
4½	2.39	3.98	4.77	5.96	7.95	9.54	11.9	14.3	15.9	17.9	19.9	21.9	23.9	27.8	31.8	35.8	39.8	43.7	47.7	51.7	55.7	0.069	0.826	15.9
5	2.95	4.91	5.89	7.36	9.82	11.8	14.7	17.7	19.6	22.1	24.5	27.0	29.5	34.3	39.3	44.2	49.1	54.0	58.9	63.8	68.7	0.085	1.02	19.6
5½	3.56	5.94	7.13	8.91	11.9	14.3	17.8	21.4	23.8	26.7	29.7	32.7	35.6	41.6	47.5	53.5	59.4	65.3	71.3	77.2	83.2	0.103	1.33	23.8
6	4.24	7.07	8.48	10.6	14.1	17.0	21.2	25.4	28.3	31.8	35.3	38.9	42.4	49.5	56.5	63.6	70.7	77.8	84.8	91.9	99.0	0.122	1.47	28.3
6½	4.98	8.30	9.96	12.4	16.6	19.9	24.9	29.9	33.2	37.3	41.5	45.6	49.8	58.1	66.4	74.7	83.0	91.3	99.6	108	116	0.144	1.72	33.2
7	5.77	9.62	11.5	14.4	19.2	23.1	28.9	34.6	38.5	43.3	48.1	52.9	57.7	67.3	77.0	86.6	96.2	106	115	125	135	0.167	2.00	38.5
7½	6.63	11.0	13.3	16.6	22.1	26.5	33.1	39.8	44.2	49.7	55.2	60.7	66.3	77.3	88.4	99.4	110	121	133	144	155	0.191	2.30	44.2
8	7.54	12.6	15.1	18.8	25.1	30.2	37.7	45.3	50.3	56.5	62.8	69.1	75.4	88.0	101	113	126	138	151	163	176	0.218	2.61	50.3
8½	8.51	14.2	17.0	21.3	28.4	34.0	42.6	51.1	56.7	63.8	70.9	78.0	85.1	99.3	113	128	142	156	170	184	199	0.246	2.95	56.7
9	9.54	15.9	19.1	23.9	31.8	38.2	47.7	57.3	63.6	71.6	79.5	87.5	95.4	111	127	143	159	175	191	207	223	0.275	3.30	63.6
9½	10.6	17.7	21.3	26.6	35.4	42.5	53.2	63.8	70.9	79.7	88.6	97.5	106	124	142	159	177	195	213	230	248	0.307	3.68	70.9
10	11.8	19.6	23.6	29.5	39.3	47.1	58.9	70.7	78.5	88.4	98.2	108	118	137	157	177	196	216	236	255	276	0.340	4.08	78.5
11	14.3	23.8	28.5	35.6	47.5	57.0	71.3	85.5	95.0	107	119	131	143	166	190	214	238	261	285	308	333	0.411	4.94	95.0
12	17.0	28.3	33.9	42.4	56.5	67.9	84.8	102	113	127	141	156	170	198	226	254	283	311	339	368	396	0.490	5.88	113
13	19.9	33.2	39.8	49.8	66.4	79.6	99.5	119	133	149	166	183	199	232	265	299	332	365	398	431	465	0.575	6.90	133
14	23.1	38.5	46.2	57.7	77.0	92.4	115	139	154	173	192	212	231	269	308	346	385	423	462	500	539	0.666	8.00	154
15	26.5	44.2	53.0	66.3	88.4	106	133	159	177	199	221	243	265	309	353	398	442	486	530	574	619	0.765	9.18	177
16	30.2	50.3	60.3	75.4	101	121	151	181	201	226	251	276	302	352	402	452	503	553	603	653	704	0.870	10.4	201
17	34.0	56.7	68.1	85.1	113	136	170	204	227	255	284	312	340	397	454	511	567	624	681	738	794	0.983	11.8	227
18	38.2	63.6	76.3	95.4	127	153	191	229	254	286	318	350	382	445	509	573	636	700	763	827	891	1.10	13.2	254
19	42.5	70.9	85.1	106	142	170	213	252	284	319	354	390	425	497	567	638	709	780	851	921	992	1.23	14.7	284
20	47.1	78.5	94.2	118	157	188	236	283	314	353	393	432	471	550	628	707	785	864	942	1021	1100	1.36	16.3	314

21	52.0	86.6	104	130	173	208	260	312	346	390	433	476	520	606	693	779	866	952	1039	1126	1212	1.50	18.0	346
22	57.0	95.0	114	142	190	228	285	342	380	428	475	523	570	665	760	855	950	1045	1140	1235	1330	1.65	19.7	380
23	62.3	104	125	156	208	249	312	373	415	467	519	571	623	727	831	935	1039	1143	1246	1350	1454	1.80	21.6	415
24	67.9	113	136	170	226	271	339	407	452	509	565	622	679	792	905	1018	1131	1244	1357	1470	1583	1.96	23.5	452
25	73.6	123	147	184	245	295	368	442	491	552	614	675	736	859	982	1104	1227	1350	1473	1595	1718	2.13	25.5	491
26	79.6	133	159	199	265	319	398	478	531	597	664	730	796	929	1062	1195	1327	1460	1593	1726	1858	2.30	27.6	531
27	85.9	143	172	215	286	344	429	515	573	644	716	787	859	1002	1145	1288	1431	1575	1718	1861	2004	2.48	29.7	573
28	92.4	154	185	231	308	369	462	554	616	693	770	847	924	1078	1232	1385	1539	1693	1847	2001	2155	2.67	32.0	616
29	99.1	165	198	248	330	396	495	594	661	743	826	908	991	1156	1321	1486	1651	1816	1982	2147	2312	2.86	34.3	661
30	106	177	212	265	353	424	530	636	707	795	884	972	1060	1237	1414	1590	1767	1944	2121	2297	2474	3.06	36.7	707
31	113	189	226	283	377	453	566	678	755	849	943	1038	1132	1321	1510	1698	1887	2076	2264	2453	2642	3.27	39.2	755
32	121	201	241	302	402	483	603	724	804	905	1005	1106	1206	1408	1608	1810	2011	2212	2413	2614	2816	3.48	41.8	804
33	128	214	257	321	428	513	641	770	855	962	1069	1176	1283	1497	1711	1924	2138	2352	2566	2780	2994	3.70	44.4	855
34	136	227	272	340	454	545	681	817	908	1021	1135	1248	1362	1589	1816	2043	2270	2497	2724	2951	3178	3.94	47.2	908
35	144	241	289	361	481	577	722	866	962	1082	1203	1323	1443	1684	1924	2165	2405	2646	2886	3127	3367	4.17	50.0	962
36	153	254	305	382	509	611	763	916	1018	1145	1272	1400	1527	1781	2036	2290	2545	2799	3054	3308	3563	4.41	52.9	1018
37	161	269	323	403	538	645	806	968	1075	1210	1344	1478	1613	1882	2150	2419	2688	2957	3226	3494	3763	4.65	55.9	1075
38	170	284	340	425	567	680	851	1021	1134	1276	1418	1559	1701	1985	2268	2552	2835	3119	3402	3686	3969	4.91	58.9	1134
39	179	299	358	448	597	717	894	1075	1195	1344	1493	1643	1792	2091	2389	2688	2986	3285	3584	3882	4181	5.17	62.1	1195
40	188	314	377	471	628	754	942	1131	1257	1414	1572	1728	1885	2199	2513	2827	3142	3456	3770	4084	4398	5.44	65.3	1257
41	198	330	396	495	660	792	990	1188	1320	1485	1650	1815	1980	2310	2641	2971	3301	3631	3961	4291	4621	5.72	68.6	1320
42	208	346	416	520	693	831	1039	1247	1385	1559	1732	1905	2078	2425	2771	3117	3464	3810	4156	4503	4849	6.00	72.0	1385
43	218	363	436	542	726	871	1089	1307	1452	1634	1815	1997	2178	2541	2904	3267	3631	3994	4357	4720	5083	6.29	75.4	1452
44	228	380	456	570	760	912	1140	1368	1521	1711	1901	2091	2281	2661	3041	3421	3801	4181	4562	4942	5322	6.58	79.0	1521
45	239	398	477	596	795	954	1193	1431	1590	1789	1988	2187	2386	2783	3181	3578	3976	4374	4771	5169	5567	6.89	82.6	1590
46	249	415	499	623	831	997	1246	1496	1662	1870	2077	2285	2493	2908	3324	3739	4155	4570	4986	5401	5817	7.19	86.3	1662
47	260	434	520	651	867	1041	1301	1561	1735	1952	2169	2386	2602	3036	3470	3904	4337	4771	5205	5639	6072	7.51	90.1	1735
48	271	452	543	679	905	1086	1357	1629	1810	2036	2262	2488	2714	3167	3619	4072	4524	4976	5429	5881	6333	7.83	94.0	1810
49	283	471	566	707	943	1131	1414	1697	1886	2121	2357	2593	2829	3300	3771	4243	4714	5186	5657	6129	6600	8.16	98.0	1886
50	295	491	589	736	982	1178	1473	1767	1963	2209	2454	2700	2945	3436	3927	4418	4909	5400	5890	6381	6872	8.50	102	1963
52	319	531	637	796	1060	1270	1590	1910	2120	2390	2650	2920	3190	3720	4250	4780	5310	5840	6370	6900	7430	9.19	110	2124
54	344	573	687	859	1150	1370	1720	2060	2290	2580	2860	3150	3440	4010	4580	5150	5730	6300	6870	7440	8020	9.91	119	2290
56	369	616	739	924	1230	1480	1850	2220	2460	2770	3080	3390	3690	4310	4930	5540	6160	6770	7390	8000	8620	10.7	128	2463
58	396	660	793	991	1320	1590	1980	2380	2640	2970	3300	3630	3960	4620	5280	5940	6600	7270	7930	8590	9250	11.4	137	2642
60	424	707	848	1060	1410	1700	2120	2540	2830	3180	3530	3890	4240	4950	5650	6360	7070	7780	8480	9190	9900	12.2	147	2827
	0.175	0.292	0.350	0.438	0.583	0.700	0.875	1.05	1.17	1.31	1.46	1.60	1.75	2.04	2.33	2.62	2.92	3.21	3.50	3.79	4.08	Hp per gallon per minute		

[1] Courtesy of Baldwin Southwark Corporation.

TABLE XII.—STEEL PIPE TABLES[1]

Nominal size	No. threads per inch	Diameter, actual external	Standard†					Bursting pressure[2]			
			Diameter, actual internal	Internal area, square inches	Capacity, gallons per 100 ft.	G. p. m. at 1 ft. per second velocity	Nominal weight, pounds per foot	Lap weld	*	Butt weld	*
1/8	27	0.405	0.27	0.06	0.295	0.18	0.24			13,750	2,500
1/4	18	0.540	0.36	0.10	0.541	0.32	0.42			13,350	
3/8	18	0.675	0.49	0.19	0.993	0.60	0.57			11,050	1,500
1/2	14	0.840	0.62	0.30	1.579	0.95	0.85			10,650	
3/4	14	1.050	0.82	0.53	2.770	1.66	1.13			8,850	
1	11½	1.315	1.05	0.86	4.490	2.69	1.68			8,275	
1¼	11½	1.660	1.38	1.50	7.770	4.46	2.27			6,900	1,000
1½	11½	1.900	1.61	2.04	10.58	6.35	2.72			6,275	
2	11½	2.375	2.07	3.36	17.43	10.5	3.65	6,750	1,250	5,325	750
2½	8	2.875	2.47	4.79	24.87	14.9	5.79	7,350		5,800	
3	8	3.500	3.07	7.39	38.40	23.0	7.58	6,425	1,000	5,050	
3½	8	4.000	3.55	9.89	51.36	30.8	9.11	5,875			
4	8	4.500	4.03	12.73	66.13	39.7	10.79	5,475			
5	8	5.563	5.05	20.01	103.9	62.4	14.62	4,825	750		
6	8	6.625	6.07	28.89	150.1	90.0	18.97	4,375			
7‡	8	7.625	7.02	38.74	201.2	121	23.54	4,000	650		
8	8	8.625	7.98	50.02	259.9	156	28.55	3,875			
8‡	8	8.625	8.07	51.16	265.8	159	24.69	3,325			
9 O.D.‡	8	9.000									
9‡	8	9.625	8.94	62.79	326.2	195	33.91	3,700			
10 O.D.‡	8	10.00							500		
10 O.D.‡	8	10.00									
10	8	10.75	10.02	78.85	409.6	246	40.48	3,525			
10‡	8	10.75	10.14	80.69	419.2	252	34.24	2,950			
10‡	8	10.75	10.19	81.58	423.8	255	31.20	2,750			
11 O.D.‡	8	11.00									
11 O.D.‡	8	11.00									
12	8	12.75	12.00	113.1	587.5	353	49.56	3,050			
12‡	8	12.75	12.09	114.8	596.4	358	43.77	2,700	450		
13 O.D.‡	8	13.00									
13 O.D.‡	8	13.00									
14	8	15.00	14.25	159.5	828.5	497	58.57	2,600			
15 O.D.‡	8	15.00									
15 O.D.‡	8	15.00									
17 O.D.‡	8	17.00									
17 O.D.‡	8	17.00									

[1] Courtesy of Baldwin Southwark Corporation.

[2] Bursting pressures (cold water) based on Barlow's formula—$P = 2f\frac{t}{D}$, where P = pressure in pounds per square inch; f = 41,000 lb. per square inch for butt-weld steel, 52,000 lb. per square inch for lap-weld steel, 62,000 lb. per square inch for seamless steel; t = thickness in inches; D = outside diameter in inches.

* Pipes serviceable for pressures indicated. If subjected to severe shocks, reduce service pressure to 75 per cent that shown.

† Seamless tubes may be had in iron pipe sizes in all weights.

‡ These sizes are not in the list included in the simplified practice recommendations of the U. S. Department of Commerce.

TABLE XII.—STEEL PIPE TABLES.[1]—(*Continued*)

Nominal size	No. threads per inch	Diameter, actual external	Extra heavy† Diameter, actual internal	Internal area, square inches	Capacity, gallons per 100 ft.	G. p. m. at 1 ft. per second velocity	Nominal weight, pounds per foot	Bursting pressure[2] Lap weld	*	Butt weld	*
1/8	27	0.405	0.22	0.04	0.189	0.11	0.31			19,800	3,500
1/4	18	0.540	0.30	0.07	0.372	0.22	0.54			19,000	
3/8	18	0.675	0.42	0.14	0.730	0.44	0.74			15,500	2,500
1/2	14	0.840	0.55	0.23	1.216	0.73	1.09			14,600	
3/4	14	1.050	0.74	0.43	2.246	1.35	1.47			11,900	2,000
1	11½	1.315	0.96	0.72	3.732	2.24	2.17			11,400	
1¼	11½	1.660	1.28	1.28	6.664	4.00	3.00		2,000	9,600	1,500
1½	11½	1.900	1.50	1.77	9.180	5.51	3.63			8,850	
2	11½	2.375	1.94	2.95	15.34	9.20	5.02	9,750	1,500	7,700	1,250
2½	8	2.875	2.32	4.24	22.02	13.2	7.66	10,100		7,950	
3	8	3.500	2.90	6.61	34.31	20.6	10.25	9,150		7,200	
3½	8	4.000	3.36	8.89	46.17	27.7	12.51	8,300			
4	8	4.500	3.83	11.50	59.72	35.8	14.98	7,900	1,250		
5	8	5.563	4.81	18.19	94.51	56.7	20.78	6,950			
6	8	6.625	5.76	26.07	135.4	81.2	28.57	6,850			
7‡	8	7.625	6.63	34.47	179.1	107	38.05	6,850			
8	8	8.625	7.63	45.66	237.2	142	43.34	6,050	1,000		
8‡	8	8.625									
9 O.D.‡	8	9.000									
9‡	8	9.625	8.63	58.43	303.5	182	48.73	5,400			
10 O.D.‡	8	10.00									
10 O.D.‡	8	10.00									
10	8	10.75	9.75	74.66	387.8	233	54.74	4,825			
10‡	8	10.75									
10‡	8	10.75									
11 O.D.‡	8	11.00									
11 O.D.‡	8	11.00									
12	8	12.75	11.75	108.4	563.3	338	65.42	4,075	750		
12‡	8	12.75									
13 O.D.‡	8	13.00									
13 O.D.‡	8	13.00									
14	8	15.00	14.00	153.9	799.7	480	77.43	3,450	600		
15 O.D.‡	8	15.00									
15 O.D.‡	8	15.00									
17 O.D.‡	8	17.00									
17 O.D.‡	8	17.00									

[1] Courtesy of Baldwin Southwark Corporation.

[2] Bursting pressures (cold water) based on Barlow's formula—$P = 2f\frac{t}{D}$, where P = pressure in pounds per square inch; f = 41,000 lb. per square inch for butt-weld steel, 52,000 lb. per square inch for lap-weld steel, 62,000 lb. per square inch for seamless steel; t = thickness in inches; D = outside diameter in inches.

* Pipes serviceable for pressures indicated. If subjected to severe shocks, reduce service pressure to 75 per cent that shown.

† Seamless tubes may be had in iron pipe sizes in all weights.

‡ These sizes are not in the list included in the simplified practice recommendations of the U. S. Department of Commerce.

TABLE XII.—STEEL PIPE TABLES.[1]—(*Continued*)

Nominal size	No. threads per inch	Diameter, actual external	Double extra heavy†								
			Diameter, actual internal	Internal area, square inches	Capacity, gallons per 100 ft.	G. p. m. at 1 ft. per second velocity	Nominal weight pounds per foot	Bursting pressure[2]			
								Lap weld	*	Butt weld	*
⅛	27	0.405									
¼	18	0.540									
⅜	18	0.675									5,000
½	14	0.840	0.25	0.05	0.259	0.16	1.71			28,900	
¾	14	1.050	0.43	0.15	0.768	0.46	2.44			24,300	4,000
1	11½	1.315	0.60	0.28	1.464	0.88	3.66			22,350	
1¼	11½	1.660	0.90	0.63	3.276	1.96	5.21		4,000	19,000	3,000
1½	11½	1.900	1.10	0.95	4.937	2.96	6.41			17,200	
2	11½	2.375	1.50	1.77	9.217	5.53	9.03	19,000	3,500	15,000	2,500
2½	8	2.875	1.77	2.46	12.80	7.68	13.70	19,950		15,750	
3	8	3.500	2.30	4.16	21.58	13.0	18.58	17,800	3,000		
3½	8	4.000	2.73	5.85	30.36	18.2	22.85	16,650			
4	8	4.500	3.15	7.80	40.54	24.3	27.54	15,600			
5	8	5.563	4.06	12.97	67.35	40.4	38.55	14,000	2,500		
6	8	6.625	4.90	18.84	97.84	58.7	53.16	13,700			
7‡	8	7.625	5.88	27.11	141.2	84.7	63.08	11,950			
8	8	8.625	6.88	37.12	192.8	116	72.42	10,600	2,000		
8‡	8	8.625									
9 O.D.‡	8	9.000	Nominal 8″ for 2500 lb. cold-water pressure								
9‡	8	9.625									
10 O.D.‡	8	10.00	Nominal 9″ for 2500 lb. cold-water pressure								
10 O.D.‡	8	10.00	Nominal 9″ for 1500 lb. cold-water pressure								
10	8	10.75									
10‡	8	10.75									
10‡	8	10.75									
11 O.D.‡	8	11.00	Nominal 10″ for 2500 lb. cold-water pressure								
11 O.D.‡	8	11.00	Nominal 10″ for 1500 lb. cold-water pressure								
12	8	12.75									
12‡	8	12.75									
13 O.D.‡	8	13.00	Nominal 12″ for 2500 lb. cold-water pressure								
13 O.D.‡	8	13.00	Nominal 12″ for 1500 lb. cold-water pressure								
14	8	15.00									
15 O.D.‡	8	15.00	Nominal 14″ for 2250 lb. cold-water pressure								
15 O.D.‡	8	15.00	Nominal 14″ for 1500 lb. cold-water pressure								
17 O.D.‡	8	17.00	Nominal 16″ for 2000 lb. cold-water pressure								
17 O.D.‡	8	17.00	Nominal 16″ for 1500 lb. cold-water pressure								

[1] Courtesy of Baldwin Southwark Corporation.

[2] Bursting pressures (cold water) based on Barlow's formula—$P = 2f\frac{t}{D}$, where P = pressure in pounds per square inch; f = 41,000 lb. per square inch for butt-weld steel, 52,000 lb. per square inch for lap-weld steel, 62,000 lb. per square inch for seamless steel; t = thickness in inches; D = outside diameter in inches.

* Pipes serviceable for pressures indicated. If subjected to severe shocks, reduce service pressure to 75 per cent that shown.

† Seamless tubes may be had in iron pipe sizes in all weights.

‡ These sizes are not in the list included in the simplified practice recommendations of the U. S. Department of Commerce.

TABLE XII.—STEEL PIPE TABLES.[1]—(*Concluded*)

Nominal size	No. threads per inch	Diameter, actual external	Seamless tube†					Bursting pressure[2]	
			Diameter, actual internal	Internal area, square inches	Capacity, gallons per 100 ft.	G. p. m. at 1 ft. per second velocity	Nominal weight pounds per foot		*
1/8	27	0.405							
1/4	18	0.540							
3/8	18	0.675							
1/2	14	0.840	0.25	0.05	0.259	0.16	1.71	43,600	
3/4	14	1.050	0.43	0.15	0.768	0.46	2.44	36,750	6,000
1	11½	1.315	0.60	0.28	1.464	0.88	3.66	33,750	
1¼	11½	1.660	0.90	0.63	3.276	1.96	5.21	28,750	
1½	11½	1.900	1.10	0.95	4.937	2.96	6.41	26,000	
2	11½	2.375	1.50	1.77	9.217	5.53	9.03	22,700	4,000
2½	8	2.875	1.77	2.46	12.80	7.68	13.70	23,800	
3	8	3.500	2.30	4.16	21.58	13.0	18.58	21,200	3,500
3½	8	4.000	2.73	5.85	30.36	18.2	22.85	19,850	
4	8	4.500	3.15	7.80	40.54	24.3	27.54	18,600	3,000
5	8	5.563	4.06	12.97	67.35	40.4	38.55	16,750	
6	8	6.625	4.90	18.84	97.84	58.7	53.16	16,350	2,500
7‡	8	7.625	5.88	27.11	141.2	84.7	63.08	14,250	
8	8	8.625	6.88	37.12	192.8	116	72.42	12,650	2,000
8‡	8	8.625							
9 O.D.‡	8	9.000	7.00	38.48	199.9	120	85.4	13,800	
9‡	8	9.625							
10 O.D.‡	8	10.00	7.75	47.17	245.0	147	107	13,950	
10 O.D.‡	8	10.00	8.50	56.75	294.8	177	74.1	9,300	
10	8	10.75							
10‡	8	10.75							
10‡	8	10.75							
11 O.D.‡	8	11.00	8.50	56.75	294.8	177	130	14,100	
11 O.D.‡	8	11.00	9.50	70.88	368.2	221	82.1	8,450	
12	8	12.75							
12‡	8	12.75							
13 O.D.‡	8	13.00	10.00	78.54	408.0	245	184	14,300	
13 O.D.‡	8	13.00	11.25	99.40	516.4	310	114	8,350	
14	8	15.00							
15 O.D.‡	8	15.00	12.00	113.1	587.6	353	216	12,400	
15 O.D.‡	8	15.00	13.00	132.7	688.9	413	150	8,250	
17 O.D.‡	8	17.00	14.00	153.9	799.5	480	248	10,950	
17 O.D.‡	8	17.00	14.75	170.9	887.8	533	191	8,200	

[1] Courtesy of Baldwin Southwark Corporation.

[2] Bursting pressures (cold water) based on Barlow's formula—$P = f\frac{t}{D}$, where P = pressure in pounds per square inch; f = 41,000 lb. per square inch for butt-weld steel, 52,000 lb. per square inch for lap-weld steel, 62,000 lb. per square inch for seamless steel; t = thickness in inches; D = outside diameter in inches.

* Pipes serviceable for pressures indicated. If subjected to severe shocks, reduce service pressure to 75 per cent that shown.

† Seamless tubes may be had in iron pipe sizes in all weights.

‡ These sizes are not in the list included in the simplified practice recommendations of the U. S. Department of Commerce.

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